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PROGRESS REPORT: STANFORD PROGRAM IN COMPUTER-ASSISTED INSTRUCTION FOR THE PERIOD JANUARY 1, 1968 TO MARCH 31, 1968.

Stanford Univ., Calif. Inst. for Mathematical Studies in Social Science.

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Descriptors-ALGEBRA, *COMPUTER ASSISTED INSTRUCTION, COMPUTER BASED LABORATORIES, *COMPUTER ORIENTED PROGRAMS, CURRICULUM DEVELOPMENT, DATA ANALYSIS, EDUCATIONAL RESEARCH, *ELEMENTARY EDUCATION, ELEMENTARY SCHOOLS, LOGIC, *MATHEMATICS INSTRUCTION, OBSERVATION, PROGRAMED INSTRUCTION, READING INSTRUCTION, RESEARCH PROJECTS, RUSSIAN, SPELLING INSTRUCTION, STUDENT BEHAVIOR, *TIME SHARING, VIDEO TAPE RECORDINGS

Identifiers-Brentwood Mathematics Program, Brentwood Reading Program, Dial A Drill Program, Stanford Brentwood System, Stanford PDP 1 System, *Stanford Program in Computer Assisted Instruction

Computer-assisted instruction was utilized in seven separate programs at Stanford involving children. In the Brentwood Mathematics program, multivariate data analysis for 73 first graders led to identification of factors affecting performance on mathematical problems. In the reading program for first and fourth graders, progress was made in curriculum development, and student behavior was observed and recorded. Extensive computer time was recorded for the drill-and-practice mathematics program for elementary students in four states, and plans were made to expand the program. Performance data for the 170 students in the tutorial logic and algebra program were analyzed, and better student dialogues with the machine were planned. Several changes were instituted in the dial-a-drill program for 14 students. The elementary Russian program continued, and the spelling program to develop optimal methods for individualized, computer-based spelling instruction generated data for the 65 children involved. A series of hardware problems plagued the Stanford PDP-1 system and the Stanford-Brentwood system, but software operations were very stable. (RS)

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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PROGRESS REPORT

STANFORD PROGRAM IN COMPUTER-ASSISTED INSTRUCTION

for the period

JANUARY 1, 1968 to MARCH 31, 1968

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Principal Investigators: Richard C. Atkinson
Patrick Suppes

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Principal Investigator: Joseph Van Campen

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INSTITUTE FOR MATHEMATICAL STUDIES IN THE SOCIAL SCIENCES
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STANFORD, CALIFORNIA

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I. Major Activities of the Reporting Period

A. Brentwood Mathematics Program

1. Student Use of Laboratory and Analysis of Results

Enrollment. Of the 72 children who began the quarter, 3 moved. During the quarter, 7 children enrolled and 3 of them were determined by their classroom teacher to be insufficiently mature to work on-line. This made a total of 73 children working on-line at the end of the quarter.

Student progress. A general notion of the children's rate of progress through the programmed curriculum can be seen in Table 1 which shows the number of children who finished a given book during a particular week.

Whereas the spread of the children at the end of the preceding quarter was from Book 6 through Book 19, at the end of this quarter the spread was from Book 11 through Book 35.

Lesson failures. So far, only the first 10 books have been completed by every child. The lesson failures for Books 1 - 5 were summarized in the report for the preceding quarter. The lesson failures for Books 6 - 10 are summarized in Table 2.

Student achievement. Tables 1 and 2 give general ideas about some phases of the children's progress. Another indicator is the proportion of the problems to which students respond correctly. Table 3 shows the number of children whose achievement for the week falls within the indicated range of percentage correct.

Group sign-on. Early in this quarter a new sign-on program, which allows a signal command to be typed for each group resulting in the automatic sign-on of every child in the group, was written and put into use. This eliminates the individual signing on of each child saving from one to three minutes before each group, and frees the person who formerly typed the individual sign-ons so that one less person is needed to prepare for a new group.

Classroom activities. The main topics studied during the quarter were telling time to the minute, the calendar, linear measure, and an introduction to graphing.

Throughout all these activities there has been an emphasis on manipulative experiences, having the children relate the topics to their own lives, verbalizing the mathematical ideas inherent in the study of these topics, and writing mathematical statements to express some of the ideas they have verbalized.

2. Curriculum Development

Plans for a revision of the second-grade mathematics curriculum have been completed. Since the major fault of this year's operation has been an intolerably long system-response time, the entire curriculum will be completely recoded in an effort to reduce response time. Other minor changes in coding will be made as the recoding is done. A complete list of coding changes follows.

TABLE 1

Number of Children Completing a Book, Brentwood Mathematics

Week of:	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Jan 2-5		2	3	3	3	3	3	3	3	2	4	2	1	1	1														
Jan 8-12		3	3	3	2	7	3	5	6	5	2	4	2	1	1	1													
Jan 15-16, 18-19		1			2	2	2	1	4	2	1	3	1	1	1	1	1												
Jan 22-26	1	1	3		3	1	4	4	3	5	7		4	1	1	1	1	1											
Jan 29-Feb 2			1	4	1	2	2	1	1	2	3	4	1	1	3	1	2	1	2										
Feb 5-9		1	4	3	1	2	2	6	4	2	3	4	7	3	2	2		2		1									
Feb 13-16			1	3	3	1	4	1	2	3	3		2	1	1	3	2		1	1									
Feb 19-21, 23				2	4	3	2	5	2	2	2	4	1	5	2	1	2	1	1	1	1	1	1						
Feb 26-Mar 1				2	2	3	1	3	3	2	1	2	3	1	5	1		3	2	2	1	1		1					
Mar 4-8				1		5	1	2	5	3		3	1	2	1	5	3		1			1	1		1				
Mar 11-15						1	3	2	5	4	3	1	5	4	2	2	4	3	2	2	1	2	1	1					
Mar 18-22					3	2	4	6	2	4	2	3	2	3	5	1	2	4		2			2	1		1	1		
Mar 25-29						1	2	5	4	4	7	1		2	2	6		2	7		2	3		1				1	1

TABLE 2

Lessons Failed in Books 6 - 10, Brentwood Mathematics

Book	Lesson	Description	Number of Failures
6	C	finding value of one dime or of n pennies	2
	D	counting from 10¢ - 19¢	4
	E	reflections about the vertical axis and rotations of congruent figures	2
	F	adding 10 + n	8
	G	choosing correct coins to buy pictured object	19
	H	adding 10 + n	5
	J	three addends, sum less than 10	5
	K	subtraction less than 10	27
	L	counting money	3
	M	review of more, less	15
	R	first, second, third, last	4
	S	three addends, sum less than 10	21
	T	10 + n	6
	U	introduction to yes-no multiple-choice format	2
	V	review equal sets	5
7	A	review of sums less than 10	9
	C	sums to 11	17
	E	distinguishing between "+" and "-"	16
	F	sums to 11	8
	H	subtraction from 10 or less	8
	I	sums to 12	35
	J	review of equal sets	3
	K	union of sets without symbol	4
	L	union of sets introducing "U"	22
	M	sums to 8 - 12	4
	N	subtraction from 10 or less, story problems	5
	R	subtraction	13
	S	sums to 12 by counting from n	24

TABLE 2 (cont'd)

Book	Lesson	Description	Number of Failures
7	U	union of three sets	11
	V	union of two or three sets	5
8	A	sums to 13	6
	B	subtraction from 10 or less	14
	C	sums to 11, 12, 13	9
	D	recognition of equations child hears read	14
	F	adding 0 to 4 - 9	2
	G	review more, less	1
	H	adding 0 - 4 to 8 and 9	4
	I	introduction to similar figures	1
	J	rotations of similar figures	5
	L	10 + n in columns	8
	M	review counting money to 19¢	10
	N	sums 10 - 13	3
	R	recognition of equations child hears read	13
	S	sums to 11, 12, 13	16
	T	review equal sets	1
	U	review union of 2 or 3 sets	2
	V	sums to 11, 12, 13	7
	W	recognition of both addition and subtraction equations child hears read	9
	X	writing an addition equation to match a simple picture story	14
9	A	conserving number	9
	C	relating $m + n = p$, $p - m = n$, and $p - n = m$	6
	D	review more, less	6
	E	subtraction from 10 or less	3
	F	introduction to counting marks on the scope	6
	J	practice subtraction from 10 or less	9
	K	relating addition and subtraction	7
	L	review equal sets	4
	M	finding different ways to make the same set	5
	N	practice subtraction from 10 or less	15

TABLE 2 (cont'd)

Book	Lesson	Description	Number of Failures
9	R	sums to 11, 12, 13	15
	S	review rotation of similar figures	1
	T	sums to 11, 12, 13	7
	U	practice subtraction from 10 or less	10
	V	introduction to open and closed figures	10
	X	writing a subtraction equation to match a picture story	28
	Y	preparation for writing subtraction equations without clues	8
10	A	writing subtraction equations	4
	D	practice subtraction from 10 or less, tallies displayed	6
	E	commutativity of sums 11 - 13	3
	F	half	3
	G	practice subtraction from 10 or less	5
	H	open figures	2
	I	sums to 11, 12, 13, column format	26
	L	review identifying circles and line segments	1
	M	column subtraction from 10 or less	17
	N	half	5
	R	sums of three numbers to 11, 12, 13	23
	T	introduction of word "minus" with problems either in vertical or horizontal format	31
	V	balancing set equations	8
	W	review rotation of similar figures	5

TABLE 3

Distribution of Children According to Percentage Correct for the Week, Brentwood Mathematics

Week of:	60 and below	61-65	66-70	71-75	76-80	81-85	86-90	91-95	96-100
Jan 2-5	1	1		6	18	13	14	17	
Jan 8-12	5	1	3	8	5	16	16	12	5
Jan 15-16, 18-19	9	1	5	1	7	9	19	7	7
Jan 22-26	3	2	3	3	11	16	20	12	2
Jan 29-Feb 2		3	4	2	13	15	19	12	5
Feb 5-9	2	5	4	4	12	12	21	11	3
Feb 13-16	2	1	2	6	9	13	18	17	5
Feb 19-21, 23	1		3	11	6	16	22	13	3
Feb 26-Mar 1	2	2		6	7	18	17	16	6
Mar 4-8	4	1	4	4	6	12	20	19	5
Mar 11-15			2	4	8	17	25	15	1
Mar 18-22		2		4	5	23	25	12	3
Mar 25-29		2	1	1	4	20	24	16	3

Coding changes.

a. Typing responses. All problems calling for a typed response will be recoded to conform to the changes made in the latter half of this year's curriculum. The major effect of this change will be to increase system-response time. The HELP and ERASE functions must be slightly modified but will not be significantly more difficult for the student. Also the displays must use character-size rather than graphic-size numerals.

b. Time-out. Almost all time-out routines in this year's material have occurred after 30 seconds. In order to allow more flexibility, the time allowance will not be coded but will be controlled by proctors using the system's LATENCY command. The proctors will then be able to use different time allowances for different groups of children or on different days. In special cases where the time-out is now set to correspond to particular curriculum requirements (either longer or shorter than the standard 30 seconds), the time allowance will be coded and will override the system LATENCY.

c. HELP. In the coding for 1967-68, two uses of the HELP routine by the student causes the answer to be displayed. In the revision this branching command will be deleted, so that repeated uses of the HELP routine produce an identical response from the system.

d. Incorrect responses. The present coding provides for the display of the correct answer after three incorrect responses; in the revision this branch command will be conditional upon two incorrect responses.

e. Mid-lesson branch. A large number of lessons in the present curriculum allow for a progress check at the mid-point; students who are clearly failing to meet criterion for the lesson are branched immediately to remedial work. In the revision, all lessons (except stories and games) will have mid-lesson branch points.

f. End-of-lesson indicator. About half of the lessons for 1967-68 include a short display to indicate the end of the lesson. These displays, containing phrases like "End of Lesson," serve as indications of progress to the student. In the revision, all lessons will be terminated in this manner.

g. Deletion of lessons. A few lessons which have proved to be unsatisfactorily written will be deleted in the revision. Also, some lessons which seem to be unnecessary will be deleted.

h. Acceleration branching. In order to make more provision for individual differences, about one-third of the lessons which have been mandatory for all students will contain provisional branching instruction to allow brighter students to bypass the lesson. The design of the criteria for the acceleration branching has not yet been completed, since it is desirable to base the decisions on data analysis which will not be completed until all data are collected for the current school year.

Extension of curriculum. Since the accelerated branching (discussed in the preceding paragraph) will allow some students to move through the curriculum much more rapidly than was the case during this year, additional material must be prepared in order to provide a sufficient number of lessons for the more able students. At present the plans are to prepare 10 more books of lessons; if time permits and if the performance of the students at the end of this year indicates a need, several more books will be prepared.

3. Production

The major effort during this reporting period has been, as usual, the continuing production of programmed lessons. As of the end of this quarter the production progress report shows the following:

Phase of production	Work completed through book
Lesson writing	65
Recording	48
Art work	49
Coding	46
Debugging	47

No significant changes in production procedures have been made.

4. Data Analysis

Individual models. The analysis of data for individual students in the first-grade mathematics program at Brentwood has been completed. The purpose of the analysis was to determine whether certain factors could predict a student's performance on a given set of lessons. Unlike the factors based on problem structure used in the "structural analysis," the factors used in this analysis were measures of prior performance of the individual. Two measures of performance were involved: the proportion of problems which the student answered correctly on the first response, and the student's average latency to the first response on correct problems.

Standard regression models were used to obtain the predictions. Two theories were involved in choosing the specific models. One theory was that the best indicator of a student's future performance is his most recent past performance. This line of reasoning led to the "temporal" models in which the prediction of an individual's performance in a given block of lessons was based on his performance in the immediately preceding blocks of lessons. The other theory was that performance depends on the degree of understanding of the information (terms, symbols, concepts, etc.) necessary to complete the new task. This idea led to the "conceptual" models in which the prediction of an individual's performance on a given set of lessons was based on his performance on previous lessons which exemplified the same concept.

Since the difference in performance for a given individual at two points in the curriculum is a function of both the "normal" variability of the individual and the particular curriculum points chosen, the parameters for the various models were estimated in two ways. The first method, estimation of group parameters, accounts for differences in performance as a function of the curriculum points examined. In this case, one set of parameters was estimated for each set of lessons with the estimation based on the performance of all students on the preceding set of lessons appropriate to the model under consideration. Thus to predict an individual's performance, a different set of parameters was used for each block of lessons; for a given block, the same set of parameters was used for all students.

The second method, estimation of individual parameters, accounts for changes in performance specific to an individual. In this case, one set of parameters was estimated for each student based on his performance on all lessons. Thus to predict an individual's performance, a set of parameters was used which was unique to that student but was the same for all blocks of lessons; for a given block, a different set of parameters was used for each student. The individual estimation technique was modified for some models to include, to some extent, differences in curriculum. Individual parameters for these models were estimated more than once, each based on a different segment of the curriculum, e.g., each set of four lessons. Thus, the set of parameters used to predict an individual's performance was unique to the individual and to the segment of the curriculum under consideration.

Comparisons of the various models were based on a total X^2 value when proportion correct was the dependent variable and on the S^2 value when latency was the dependent variable (Suppes, Hyman, and Jerman, 1967). For proportion correct, the conceptual models predicted individual performance better than the temporal models with both the group and the individual parameter estimation techniques. Thus, a student's performance on a given topic is more dependent upon his past performance on that topic than upon his more recent performance on a different topic. For latency data, there were no differences between the temporal and conceptual models.

Again, considering data in terms of proportion correct for both the temporal and conceptual models, group parameters gave better predictions than the individual parameters. For the temporal models, the modified individual estimation technique yielded predictions which were better than the individual parameters based on all the student data, but were not as accurate as the group parameter predictions. For the latency data, all models based on group parameters were better than the models estimated by individual parameters.

Regression analyses of group data on individual items. Five concepts in the first-grade mathematics curriculum were completed. Variables were defined to reflect problem structure and to predict proportion correct and success latency. The results have been tabulated and will be presented in a forthcoming report. The multiple-correlation coefficients for proportion correct ranged from .50 for counting to .72 for subtraction, while those for success latency ranged from .67 for geometry to .87 for sets.

Following are examples of variables and the results obtained for the regressions. In predicting proportion correct for addition problems, the following variables were defined:

X_{+1} - number of symbols on the cathode-ray tube;
X_{+2} - the largest addend;
X_{+3} - the smallest addend;
X_{+4} - the sum;
X_{+5} - the value of the smallest incorrect response alternative divided by the difference in value between the smallest incorrect response alternative and the correct choice;
X_{+6} - two if the blank is to the left of the equal sign and to the left of the plus sign. One if the blank is to the left of the equal sign and to the right of the plus sign;
X_{+7} - one if a typed response is required in a problem.

In predicting success latency for subtraction problems, the following variables were defined:

X_{-1} - the diminuend;
X_{-2} - the subtrahend;
X_{-3} - the difference;
X_{-4} - one if counting marks were displayed, but the number equal to the subtrahend were not crossed out or no counting marks were displayed;
X_{-5} - one if no counting marks were displayed;
X_{-6} - the magnitude of the inverse of the number of times which a specific problem had been given up to that point in the curriculum;
X_{-7} - one if a problem had a vertical format.

The regression coefficients and multiple-correlation coefficient for the addition and the subtraction blocks are shown in Table 4. The regression analysis was successful in predicting proportion correct for the subtraction problems; less information was obtained for the addition problems.

TABLE 4

Regression Coefficients for Group Probability Analysis, Brentwood Mathematics

Concept	Number of Problems	Constant	$X_{.1}$	$X_{.2}$	$X_{.3}$	$X_{.4}$	$X_{.5}$	$X_{.6}$	$X_{.7}$	R
Addition	161	-1.18	-.01*	.11*	.16*	-.06*	.22*	.84	-.63	.51
Subtraction	64	5.28	-.63*	.93	.94	-1.51	3.26	-2.58	-.80	.82

*t score for regression coefficient < 2.00

As a result of the analyses of the first-grade mathematics data, a number of the factors which affect performance on mathematics problems were identified. These results are now being utilized in a similar analysis of the second-grade mathematics curriculum.

B. Brentwood Reading Program

1. Curriculum Development

Levels VII and VIII of the reading curriculum were completed. A revised comprehension section which can be implemented at any date has been planned for Level VIII. Supplementary materials and the Teacher's Manual for Levels II and III have been distributed to the Brentwood teachers.

2. Coding

Every lesson through Level VII has been coded, keypunched, and has had at least one card assembly. Levels IV and V have been ready for student use since January. Almost half of the detecting and correcting has been done for Levels VI and VII to prepare them for student use.

3. Student Use of Terminals

Enrollment and progress. At the end of the reporting period, 80 first-grade students and 7 remedial fourth-grade students, who began work on March 13, were working on the reading curriculum. Table 5 indicates the number of first-grade students in each lesson at the end of the thirteenth through the twenty-fifth weeks. Behavior and progress of the fourth graders will be described in the next quarterly report.

The underlined figure in each column represents the maximum progress by the fastest student during that same week last year. By the end of the thirteenth week, this year's fastest student had completed 21 lessons more than last year's fastest student; by the end of the twenty-fifth week, he had completed 23 lessons more. The increasing spread of the students over the lesson material indicates that at least some of the individual differences in the learning characteristics of the student population are being accommodated in the curriculum. Table 5 also indicates two factors affecting the rate

TABLE 5

Weekly Distribution of First-Grade Students in Each Lesson

(January 2 - March 29)

Brentwood Reading

	Week Number	13	14	15	16	17	18	19	20	21	22	23	24	25
	Number of Students	77	78	77	75	75	78	77	77	78	79	80	80	80
Lesson Number	Letters-1	6	2	1	0	0	0	0	0	1	0	1	0	1
	I-1	1	3	2	0	0	4	3	1	1	2	2	2	2
	2	0	1	3	4	1	1	2	2	1	2	3	2	0
	3	9	8	8	1	3	2	0	2	3	1	0	1	2
	4	3	3	1	7	6	4	8	3	2	2	2	1	1
	5	8	8	7	6	4	3	3	5	3	3	3	4	3
	Letters-2	0	0	2	0	2	2	0	2	1	0	0	0	1
	6	2	2	2	3	3	5	3	3	4	4	3	0	0
	7	9	7	8	11	12	12	11	3	5	4	3	4	2
	8	3	4	4	1	1	1	2	11	3	3	3	3	2
	9	3	2	2	4	3	1	1	2	11	9	3	2	3
	10	4	5	1	1	2	2	2	0	1	6	9	7	3
	11	0	2	4	2	2	1	1	3	0	0	4	3	3
	12	2	3	5	4	2	5	4	2	3	1	3	6	7
	13	0	0	0	3	5	1	3	3	3	2	0	2	5
	Letters-3	0	0	0	0	0	0	0	2	0	3	0	0	1
	II-1	3	1	0	1	0	2	0	0	2	1	3	1	0
	2	2	3	2	0	2	3	5	2	0	2	3	1	3
	3	5	2	1	2	0	1	0	2	0	1	1	3	0
	4	1	2	1	0	1	1	0	0	3	0	1	2	2
	5	1	4	5	3	1	0	1	0	2	3	0	0	2
	6	1	0	2	1	0	1	1	1	0	1	1	2	1
	7	0	1	2	6	6	5	6	3	1	1	4	1	2
	8	1	0	0	1	3	2	0	2	2	1	0	3	1
	9.1	2	0	0	0	0	0	2	2	1	0	0	1	3
	9.2	0	3	0	0	2	3	1	1	3	3	1	0	1
	10	3	1	3	0	0	2	2	4	2	4	5	2	0

TABLE 5 (cont'd)

	Week Number	13	14	15	16	17	18	19	20	21	22	23	24	25
	Number of Students	77	78	77	75	75	78	77	77	78	79	80	80	80
Lesson Number	11	2	1	1	1	0	0	1	0	2	0	1	1	1
	12	0	2	1	3	0	0	1	0	2	1	1	2	1
	13	0	1	0	0	1	0	0	0	0	2	0	2	1
	14	0	0	3	1	2	0	0	2	0	2	2	0	3
	15	1	0	0	0	2	2	0	0	1	0	3	3	1
	16	0	0	0	2	0	1	2	0	1	1	0	1	0
	17	2	0	0	1	1	0	0	0	0	0	0	0	0
	18	1	2	0	0	0	0	1	1	0	0	0	0	1
	19	0	0	0	0	0	0	0	0	0	0	0	0	0
	III-1	1	2	1	0	1	3	0	1	1	1	1	2	3
	2	0	1	0	0	1	0	2	1	0	0	1	0	2
	3	0	1	2	0	0	0	1	0	2	1	0	0	0
	4	1	0	2	1	0	2	0	2	0	1	1	2	0
	5		1	0	2	0	0	0	1	0	1	1	1	0
	6			0	1	0	0	2	0	2	0	1	0	2
	7			1	0	0	0	0	0	0	0	0	1	0
	8				1	1	0	0	0	1	0	0	0	1
	9				0	2	0	0	2	0	3	0	1	1
	10				0	1	1	0	0	0	0	0	0	0
	11				1	1	3	0	0	0	0	2	0	1
	12					1	1	4	0	2	0	1	1	0
	13						1	1	2	0	2	0	2	0
	14							0	3	0	0	1	0	1
	15							1	0	2	0	1	0	2
	16								0	1	2	0	1	0
	17								1	2	0	1	0	0

TABLE 5 (cont'd)

	Week Number	13	14	15	16	17	18	19	20	21	22	23	24	25
	Number of Students	77	78	77	75	75	78	77	77	78	79	80	80	80
Lesson Number	18									0	1	2	3	1
	19									1	2	0	0	0
	20										0	2	1	2
	21										0	0	0	0
	22										1	0	0	1
	23											1	2	0
	IV-1												0	3
	2												0	0
	3												1	0
	4													0
	5													1

of progress. First, there has been considerable demographic movement in the student population; accordingly, none of the children in the early lessons of Level I represent students who began work in September 1967. Second, the table reflects the increasing complexity of the lessons in Levels III and IV. The children begin work on compound and polysyllabic words in Level III and begin reading short stories to themselves in Level IV. Thus, the time required to complete a lesson is considerably longer.

Student terminal behavior. During this reporting period, graduate students in the Experienced Teacher Fellowship Program have observed and recorded student behavior and attitudes. These observations were made two times during the school year for each student. Table 6 indicates the results of children's behavior on the first set of observations while working at the CAI terminals. The results of the second set of observations will be reported in the next quarterly report. Eight basic categories of behavior were outlined. Each child was observed for 5 minutes at the beginning, in the middle, and at the end of a period. During each 5-minute period, the observer checked the type of behavior displayed every 15 seconds. Thus, for the entire sample of 73 students, any specified behavior could be observed a maximum of 20 times during the 5-minute period for a given student. Variable 1 (looking at scope or projector) would represent a desirable behavior, while Variables 2-8 would be undesirable. The table indicates that Variable 1 was in predominance with a mean of 17.2 out of a possible 20 for the entire sample. The columns headed "Maximum" and "Minimum" indicate that although there was at least one student who exhibited the desirable behavior only eight times in the observation period, there were several children who exhibited the desirable behavior a near maximum number of times (i.e., 20 times). The means for Variables 2-8 indicate that a minimal amount of undesirable behavior was found. Often the child displayed these forms of behavior while the system was functioning at a slower than normal rate.

4. Weekly Report

A weekly report was generated to provide information about student progress to the teachers and proctors. The report will also assist in identifying learning difficulties experienced by the students in sufficient detail so corrective measures can be determined and implemented. The information is derived from the recorded responses of the students. These recorded responses include the following: date; relative response time; student identification number; identification of the problem to which the student responded; the actual response coordinates; the nature of the response, i.e., correct, wrong, overtime, unidentifiable; latency in making the response; the records of positions of various switches and the contents of various counters used in curriculum sequencing and branching procedures.

TABLE 6

Results of Children's Behavior Working at CAI Terminal

Brentwood Reading

Observed behavior	Var. no.	Mean	S.D.	S.E. of Mean	Sample	Maximum	Minimum	Range
Looking at scope or projector	1	17.2	3.0	0.4	73	20.0	8.0	12.0
Twists in chair	2	3.8	3.0	0.3	73	14.0	0.0	14.0
Watching others	3	1.0	1.7	0.2	73	9.0	0.0	9.0
Looking over or under partitions	4	0.1	0.5	0.1	73	4.0	0.0	4.0
Playing with keyboard	5	0.1	0.4	0.1	73	3.0	0.0	3.0
Playing with light pen	6	0.2	0.7	0.1	73	4.0	0.0	4.0
Playing with projector or scope	7	0.1	0.4	0.1	73	3.0	0.0	3.0
Looking or making faces in mirrors	8	0.0	0.2	0.0	73	1.0	0.0	1.0

The student's rate of progress through the curriculum is dependent on four different branching sequences: (a) any repetition within a specific problem type using optimization procedures; (b) repetition of problem types previously passed to obtain additional practice to pass successive problem types; (c) use of additional remedial material to compensate for apparent deficiencies in student experience; and (d) the branching of the student to "off-line" tutorial help given by a teacher. A proctor branches the student to off-line remedial help when the CAI system indicates that the student has been working on a single block of problems for more than two days. The off-line remedial help lasts a minimum of one full session and is continued on sequential days at the discretion of the teacher.

The sequence of problem types to which the student is exposed each day within any one lesson, and within a week, records the path a student follows through the curriculum. The problem types begun each day are printed and slashes are inserted when the date changes. Table 7 shows a typical sequence of problem types.

At the beginning of each daily session the student is returned to the initial problem of the type he was doing when the previous session was terminated. Therefore, the same problem type commonly occurs twice in sequence--before and after a change in date. The number of problem types encountered each day is noted, and the sum of the daily counts for the lesson or for the week is recorded as shown in Table 7.

By providing information about the nature of student responses, the weekly report is useful in attempting to answer the following general questions:

1. Does the student understand the types of responses expected of him?
2. Is the student attending to the task presented him?
3. Is the student having visual-muscular coordination problems while attempting to respond?

Student responses are catalogued into one of four categories: correct responses, anticipated wrong responses, unanticipated or unknown responses, and overtime responses. The fourth category describes responses made after the time preassigned for the problem type.

The distribution of both overtime responses and unknown answer responses may suggest different types of difficulties. For example, if a student consistently makes strings of unknown responses, he may be having difficulty either with muscular coordination or in understanding directions. Similarly, extensive strings of overtime responses would suggest that the student is not attending to the task presented him or, again, that he does not understand the instructions. Each week the proctors receive distributions of overtime and unknown responses for each lesson within the week. The distribution of overtime and unknown responses is also sorted for three of the major blocks within the curriculum (word list, matrix, and comprehension) as shown in Table 8.

TABLE 7

Student's Sequence Through Lessons

Brentwood Reading

Weekly Report
Student Number - Name
J104 John Cannon

Date	Lesson	Student's sequence through lesson
3-18-68	AI	WA WP WC WN // WN WP WC GB 3 MA 3 MD // MA MB MC MD MT MI // MT MI MF MT CU // CF CW No. of Pt's = 23

TABLE 8

Distributions of Strings of OT's and UU's

Brentwood Reading

Weekly Report
Student Number - Name
J104 John Cannon

Block	$S(OT)^a/S(C+K+W)^b$	Distribution of Strings of OT's^c 1	2	3	4	5	6	Other	$S(UU)^d/S(C+K+W)$	Distribution of Strings of UU's^e 1	2	3	4	5	6	Other
(ALL)	37/305	22	4	1	1	0	0	0	33/305	13	5	2	1	0	0	0
WX	7/47	5	1	0	0	0	0	0	2/47	2	0	0	0	0	0	0
MX	21/103	10	2	1	1	0	0	0	24/103	8	3	2	1	0	0	0
CX	12/78	3	1	0	0	0	0	0	7/78	5	2	0	0	0	0	0

[a] $S(OT)$ = Sum of overtime responses

[b] $S(C+K+W)$ = Sum of all identifiable responses: correct (1), correct (2), incorrect.

[c] OT = Overtime responses

[d] $S(UU)$ = Sum of unknown responses

[e] UU = Unknown responses

The optimization routine used in some of the major blocks in the curriculum provides a method by which a student is corrected and repeats each of the problems missed until he has correctly responded to each problem without assistance. To determine whether or not this procedure is facilitating learning, the ratio of the number of original problems missed to the total number of times the student had to attempt the problem is computed. If this ratio is 1.00, the student learned with one correction on each problem. Values less than 1.00 show that, on the average, the student requires more corrections for each original problem missed, e.g., .5 indicates two trials per problem. This ratio is computed, printed, and labeled the coefficient of interaction.

In addition to the coefficient of interaction, the percentage correct on the first unassisted trial for each problem within a problem type is computed and printed. This computation does not consider any responses made while the student was being assisted through the correction procedure. Two additional values are computed and printed: (a) the number of problems in the problem type; and (b) the overall proportion correct on the unassisted trials. Table 9 shows these computations on a weekly report for a typical student.

5. Data Analysis

Data from the daily reports has been assembled to show how the amount of time spent on the computer relates to a student's progress through the curriculum. A student's progress is measured by the number of problem types completed, e.g., screening test, word block, matrix block, sentence initiators, compound words, contractions, etc. A measure of problem types completed gives a more accurate evaluation of a student's rate of progress as the problem types cover more nearly equal units of curriculum than do the lessons. A single lesson may contain from 4 to 20 different problem types (PT's). A problem type is counted only once. Thus, when a student repeats any part of the curriculum, those repeated problem types are not added to his total of problem types completed. Only main-line problem types are counted; remedial problem types are not considered.

From these daily reports a weekly summary has been compiled providing the following information for each child: (a) the number of minutes on the computer during the week; (b) the cumulative time on the computer to date; (c) the lesson and PT completed at the end of each week; (d) the total PT's completed to date; and (e) the number of PT's completed during the week.

Figure 1 indicates the progress of three selected students from October 13, 1967 to March 15, 1968. N5 is the student who has progressed the furthest. M1 has made moderate progress, and J1 is one of the students who has shown the least progress. In each case the line representing his rate of progress approximates a straight line. There is a

TABLE 9

Computational Information, Brentwood Reading

Weekly Report
Student Number - Name
J104 John Cannon

No. of problems	Initial per cent correct	Interaction coefficient	Overall per cent correct
N1(WA) = 7	PC1(WA) = 5/ 7 = 0.714	K(WA) = 2/ 3 = 0.667	PC(WA) = 7/ 10 = 0.700
N1(WP) = 7	PC1(WP) = 6/ 7 = 0.857		
N1(WC) = 7	PC1(WC) = 2/ 7 = 0.285		
N1(WN) = 7	PC1(WN) = 7/ 7 = 1.000	K(WN) = 0/ 0 = 0.000	PC(WN) = 7/ 7 = 1.000
N1(WP) = 6	PC1(WP) = 6/ 6 = 1.000		
N1(WC) = 7	PC1(WC) = 4/ 7 = 0.571	K(WC) = 3/ 6 = 0.500	PC(WC) = 7/ 13 = 0.538
N1(GB) = 27	PC1(GB) = 8/ 27 = 0.296		
N1(MT) = 9	PC1(MT) = 3/ 9 = 0.333		
N1(MT) = 9	PC1(MT) = 4/ 9 = 0.444		
N1(MI) = 7	PC1(MI) = 5/ 7 = 0.714	K(MI) = 2/ 3 = 0.667	PC(MI) = 7/ 10 = 0.700
N1(MF) = 7	PC1(MF) = 4/ 7 = 0.571	K(MF) = 3/ 4 = 0.750	PC(MF) = 7/ 11 = 0.636
N1(MT) = 9	PC1(MT) = 7/ 9 = 0.778	K(MT) = 2/ 2 = 1.000	PC(MT) = 9/ 11 = 0.818
N1(CU) = 9	PC1(CU) = 7/ 9 = 0.777		
N1(CF) = 6	PC1(CF) = 1/ 6 = 0.166		
N1(CW) = 9	PC1(CW) = 7/ 9 = 0.777		

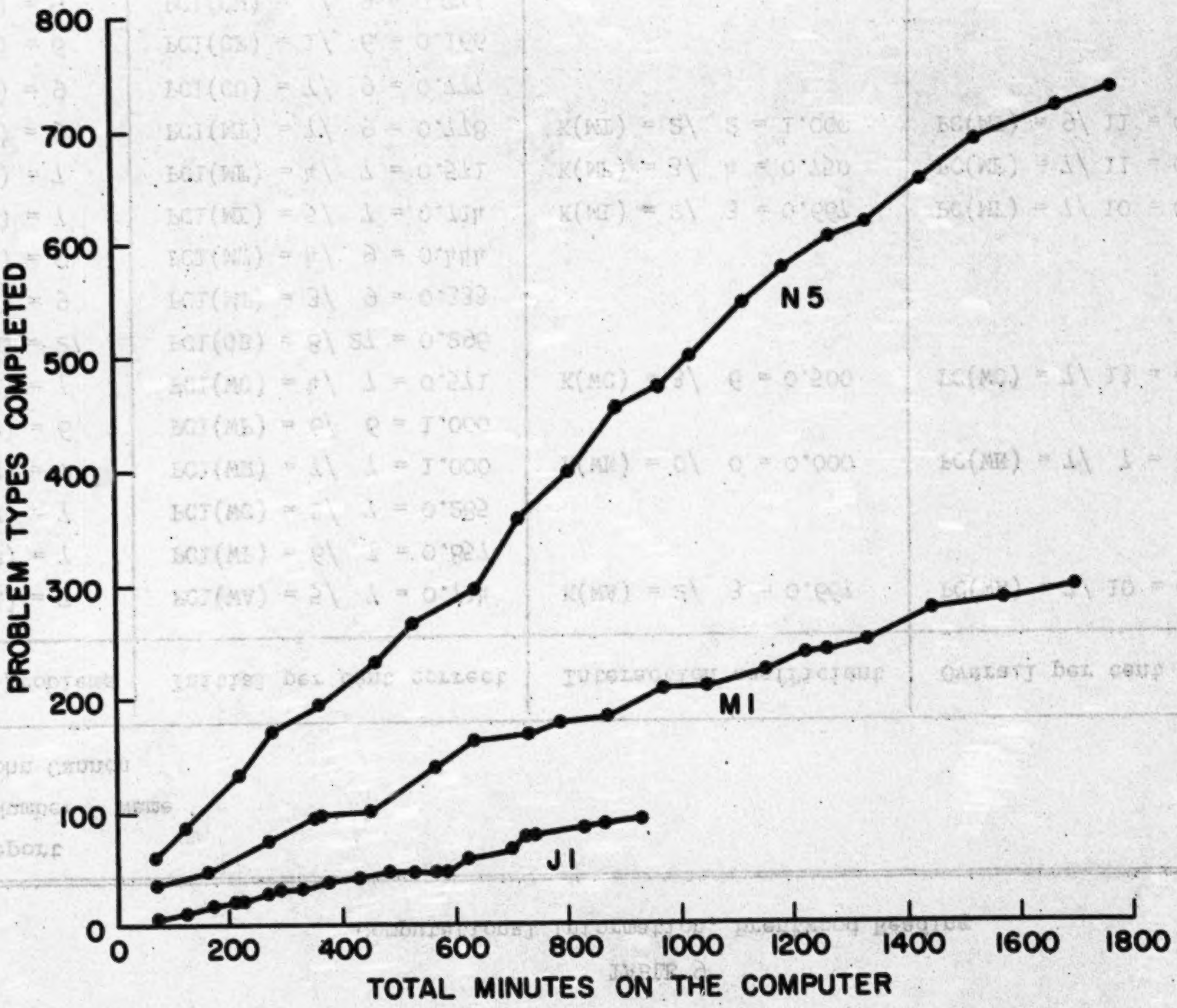

Figure 1. Weekly Progress of Three Students from October 13, 1967 through March 15, 1968, Brentwood Reading

noticeable change in the rate of progress (slope) as the student moves into Level II (PT 160). The increase in rate shown by J1 at about 600 minutes probably is explained by the practice of proctoring students through the matrix block after they have been working on a matrix block for two consecutive days. The figures indicate that student rate of progress during this reporting period has been essentially linear.

The scatter diagram shown in Figure 2 locates each student by the time he has spent on the computer and by his progress through the curriculum. The diagonal lines from the origin indicate progress rates in minutes per problem type. Eight students progressed at a rate faster than 3 minutes per problem type. The median rate is about 6 minutes per problem type. About 20 per cent of the pupils progress at a rate slower than 10 minutes per problem type.

Figure 3 indicates the average time efficiency of the system. In computing the average time spent on the computer per day, the number of minutes spent on the computer each session is totalled for the week and divided by the number of student days. A student day is considered to be two minutes or more of work. Days when the student is off-line for remedial help, and days when machine failure results in no time on the computer, are not counted. Figure 3 indicates the time efficiency of the system to be about 70 per cent, with a range from 50 to 80 per cent. Time lost is due to machine failure during a session, lesson turn-around time, and interruptions for discipline or explanation.

C. Drill-and-practice Mathematics Program

1. Use of the System in Schools

The number of students given daily lessons remained fairly constant in spite of the addition of three new elementary schools in Kentucky. The total number of students given lessons each day at each school is shown in Table 10. The formal starting date of the new elementary schools in Kentucky is also indicated. Students "signed on" the system at least 86,192 times, which is the total number of student entries in Table 10.

A workshop for teachers and administrators was held at Morehead State University, Morehead, Kentucky, February 1 - 3. The program of the workshop emphasized (a) behavioral definitions of instructional objectives; (b) projection of the year's mathematics work in detail and selection of appropriate drill-and-practice lessons to supplement the planned course of instruction; and (c) practice on instructional terminals as students. In addition, participants in the workshop were given instruction on simple maintenance procedures for the instructional terminals.

Table 11 shows the actual number of students enrolled in the program as of March 29 at each grade level at each school. The numbers represent students taking lessons at a given grade level, regardless of their actual grade placement in school with the

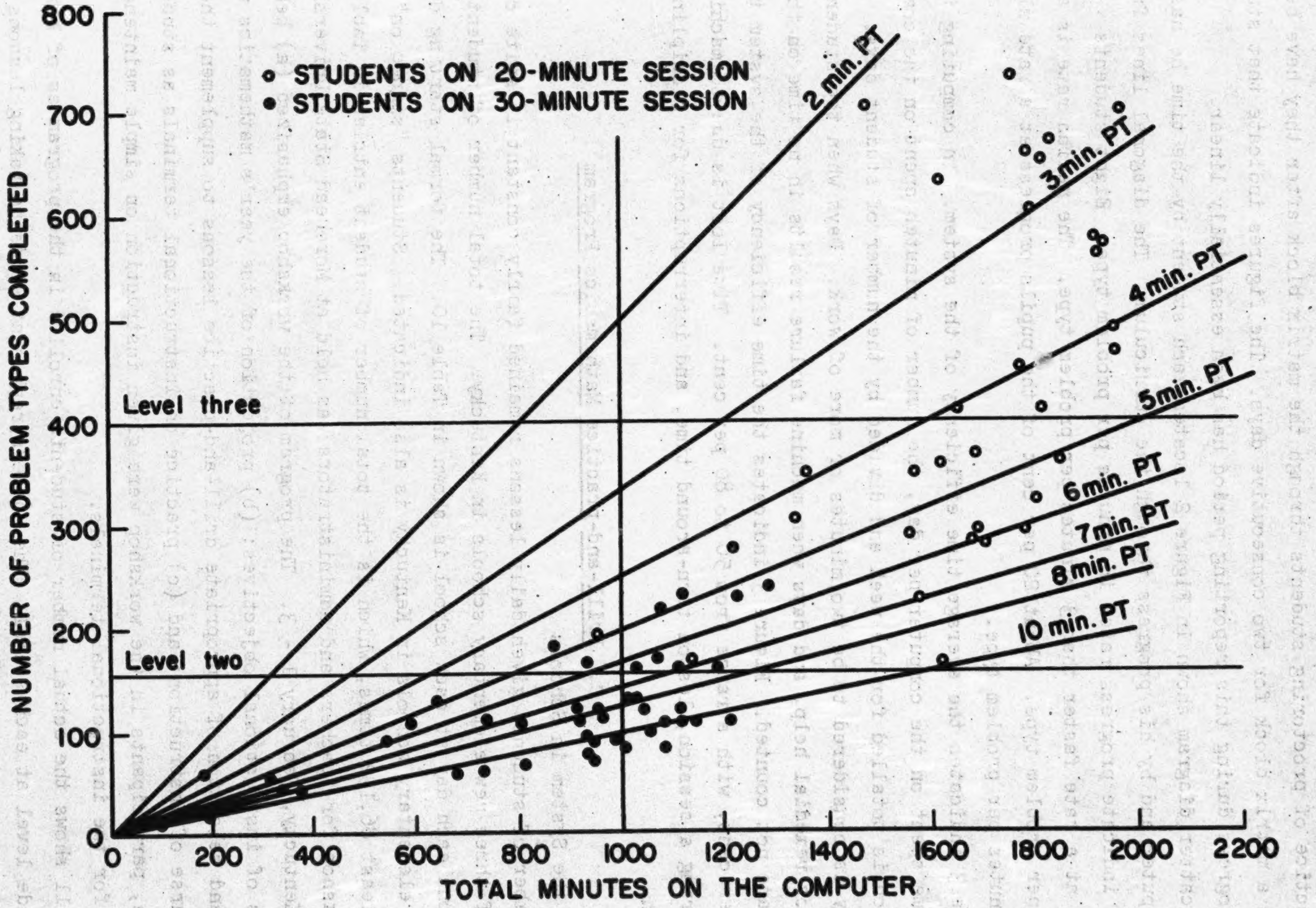

Figure 2. Distribution of Students by Lesson Material and Time on Computer as of March 15, 1968, Brentwood Reading

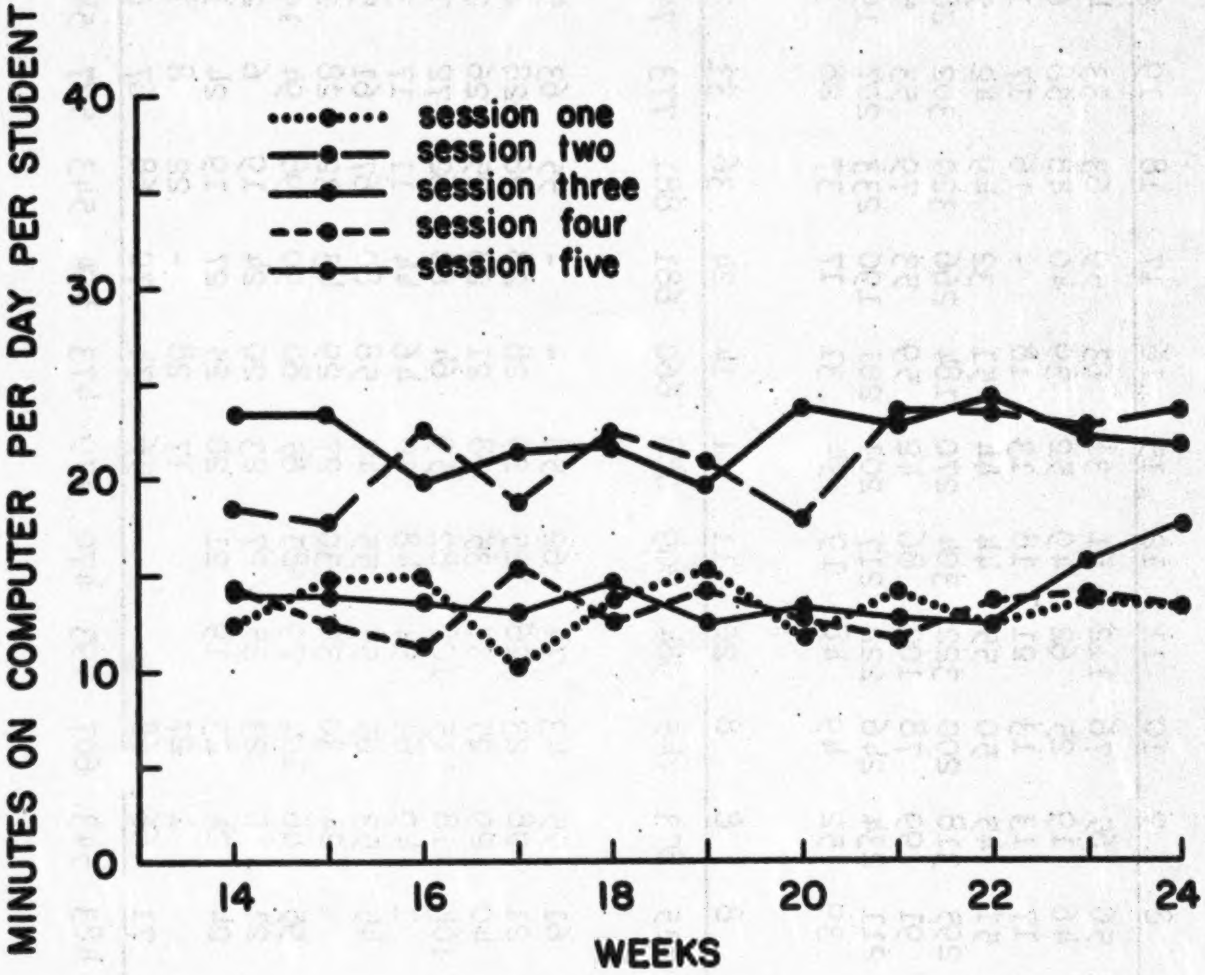

Figure 3. Average Time on Computer per Student for each Session , Brentwood Reading

TABLE 10

Number of Students Given Daily Lessons at Each School (Including Logic Students)

Drill-and-Practice Mathematics

	January 2	3	4	5	8	9	10	11	12	15	16	17	18	19	22	23	24	25	26	29
Calif. schools																				
Lab	21	55	17	79	56	65	76	112	61	31	63	59	63	33	41	64	118	89	47	47
Grant	21	78	38	45	46	19	25	62	49	52	39	40	48	58	63	59	50	62	66	76
Garden Oaks	2	13	21	12	17	13	13	21	18	13	18	-	16	17	10	27	21	21	21	10
Peter Burnett	31	53	48	46	51	45	50	55	44	44	51	32	49	42	52	52	50	39	28	37
Walter Hays	110	293	329	312	295	318	200	322	304	270	184	266	320	302	281	311	292	260	275	117
Oak Knoll	9	52	103	95	91	99	78	102	86	42	59	53	79	53	56	75	81	95	83	78
Clifford	72	237	232	239	211	234	246	222	217	201	201	190	233	207	190	215	218	222	-	205
Fremont Hills	2	43	61	46	39	52	49	48	19	34	31	17	37	28	34	35	38	39	44	30
Iowa																				
Clinton Job Corps Ctr.			49	18	8	8	8	20	11	1	14	24	36	33	38	19	15	39	6	40
Sub-total	268	824	898	892	815	853	745	984	809	688	660	681	881	773	748	857	883	866	570	640
Miss. Schools																				
Eva Gordon	Mississippi PDP-8 Down			53	61	55	43	74	62	58	-	-	55	63	58	67	63	30	59	-
Alpha Center				18	21	28	23	26	25	29	28	28	28	28	23	29	24	31	24	-
Kennedy				22	40	29	25	37	35	28	21	28	25	26	26	24	19	20	1	-
Universal				79	104	118	115	108	82	59	64	60	62	72	70	67	95	86	89	-
Westbrook					1	49	61	54	48	50	46	44	11	7	32	40	58	25	27	-
Taggart				25	45	53	65	55	55	47	58	80	67	61	54	56	56	53	44	-
Netterville				16	1	24	30	36	30	27	29	43	32	28	27	25	31	31	25	-
Otken				31	95	86	104	79	85	65	80	90	98	94	100	85	98	60	101	-
Hughes				16	21	10	23	25	27	23	20	24	19	6	21	26	26	26	25	-
Summit				26	24	24	23	19	21	20	25	27	19	24	18	14	27	24	23	-
Lillie M. Bryant						1	27			17	28	-	22	8	10	3	15	9	24	-
Franklin Center				64	71	66	68			56	74	70	68	67	65	66	54	62	63	-
Sub-total				350	483	543	607	493	470	479	473	494	543	527	542	521	581	496	505	0
Ky. schools																				
Brekenridge																	25	101	52	229

TABLE 10 (cont'd)

	January		February																	
Calif. schools	30	31	5	6	7	8	9	12	13	14	15	16	19	20	21	23	26	27	28	29
Lab	104	87	55	76	89	88	100	33	82	139	85	63	62	82	112	25	16	81	103	80
Grant	79	66	24	49	114	85	116	-	89	72	79	89	95	96	81	6	63	68	89	93
Garden Oaks	29	10	-	12	20	17	7	-	14	13	16	15	13	16	9	-	14	27	32	16
Peter Burnett	33	40	18	32	35	40	41	-	37	47	48	53	48	63	57	-	29	51	14	75
Walter Hays	297	209	176	261	344	287	289	1	285	295	327	300	283	317	294	-	215	307	230	141
Oak Knoll	121	95	23	50	96	85	79	-	99	101	109	97	1	2	2	-	62	90	113	97
Clifford	224	212	117	214	222	225	213	-	229	213	233	231	234	246	209	-	194	217	213	214
Fremont Hills	47	39	12	22	40	42	43	-	49	34	37	46	31	42	29	-	17	37	49	32
Iowa																				
Clinton Job Corps Ctr.	56	38	12	23	43	60	45	-	45	15	12	27	31	18	21	51	8	16	51	39
Sub-total	990	796	437	709	703	929	933	34	929	929	946	925	798	882	814	81	618	894	894	787
Miss. schools																				
Eva Gordon	60	68	9	36	35	52	55	51	50	43	56	72	44	57	56	-	43	41	42	50
Alpha Center	27	26	14	42	56	53	54	44	58	45	39	52	49	53	46	-	23	56	47	52
Kennedy	31	27	-	26	37	23	28	31	19	14	17	27	23	23	34	-	18	21	30	25
Universal	104	65	9	97	131	85	82	115	127	82	130	114	122	141	107	-	77	118	112	123
Westbrook	18	29	11	52	50	36	56	56	48	36	56	45	52	50	45	-	47	64	50	42
Taggart	86	96	22	69	71	44	88	64	81	42	78	60	59	81	71	-	43	76	88	85
Netterville	56	27	-	55	41	29	34	39	27	28	30	23	23	30	31	-	20	53	58	58
Otken	94	98	24	85	98	78	95	84	64	71	78	85	77	74	80	-	54	62	98	82
Hughes	26	17	-	27	26	15	25	30	7	22	21	25	28	34	33	-	25	29	22	30
Summit	25	29	5	31	27	29	31	17	33	26	31	31	29	28	30	-	27	31	39	34
Lillie M. Bryant	18	20	11	29	20	25	30	29	20	27	32	25	27	24	25	-	23	22	41	25
Franklin Center	56	24	17	47	9	57	77	97	101	64	92	119	75	114	105	-	62	107	96	96
Sub-total	601	526	122	596	601	526	645	657	635	500	660	658	608	709	663	-	462	680	723	702
Ky. schools																				
Brekenridge	274	243	-	235	241	191	276	31	218	201	248	284	273	88	262	258	63	114	248	213

TABLE 10 (cont'd)

	March																				
Calif. schools	1	4	5	6	7	8	11	12	13	14	15	18	19	20	21	22	25	26	27	28	29
Lab	95	61	63	54	73	84	87	70	139	222	198	129	39	22	55	6	103	90	67	73	166
Grant	83	52	91	76	94	80	73	94	110	85	62	84	70	32	60	19	65	69	69	77	46
Garden Oaks	14	20	20	18	14	7	20	19	20	13	7	17	13	16	19	1	18	13	16	26	6
Peter Burnett	49	55	64	66	58	60	62	71	71	59	68	67	71	65	78	8	66	59	61	49	65
Walter Hays	106	97	87	115	96	113	257	296	289	316	243	321	163	253	300	46	302	290	302	295	251
Oak Knoll	102	98	95	136	107	109	116	110	115	123	118	132	114	120	144	28	124	134	136	128	126
Clifford	214	191	223	230	215	218	233	222	229	226	227	222	218	204	225	60	224	229	230	226	1
Fremont Hills	33	36	40	32	34	33	44	35	48	46	47	45	49	42	51	10	47	51	48	40	45
Iowa																					
Clinton Job Corps Ctr.	37	5	25	36	29	24	22	17	14	4	1	1	3	12	5	1	2	19	7	10	19
Sub-total	789	615	780	763	720	728	914	934	1035	1094	971	1018	740	766	937	179	911	954	936	924	725
Miss. schools																					
Eva Gordon	65	53	61	53	53	51	63	61	49	32	34	1	3	-	-	-	40	53	50	44	6
Alpha Center	42	41	59	54	51	42	36	41	44	47	41	-	-	-	-	-	38	40	39	42	29
Kennedy	16	26	-	21	20	18	-	-	-	-	-	8	23	21	22	10	16	17	15	13	14
Universal	123	127	-	90	102	83	115	82	93	82	77	1	-	2	-	-	79	69	88	93	103
Westbrook	49	53	61	61	63	50	62	53	63	75	71	-	-	-	-	-	63	74	67	46	64
Taggart	83	76	80	101	117	80	101	107	99	44	48	-	-	-	-	-	78	56	67	114	92
Netterville	55	30	37	39	40	40	-	-	-	-	-	29	33	32	30	17	25	38	28	41	32
Otken	74	96	101	68	68	62	-	-	-	-	-	32	74	78	62	43	75	75	77	75	84
Hughes	26	29	30	41	26	26	-	-	-	-	-	20	26	26	33	19	21	24	26	26	26
Summit	25	22	36	29	24	24	-	-	-	-	-	33	15	28	27	9	23	32	26	26	31
Lillie M. Bryant	38	38	27	31	27	17	23	22	30	25	32	-	-	-	-	-	14	25	29	32	23
Franklin Center	90	87	92	82	84	86	-	-	-	-	-	40	74	90	98	9	92	90	98	99	97
Sub-total	686	678	704	670	675	579	400	366	378	305	303	164	247	277	272	107	604	593	610	651	601
Ky. schools																					
Brekenridge	255	207	252	233	253	262	249	266	245	343	270	284	-	-	-	183	270	250	274	224	216
Elliotsville		14	16	39	53	53	65	59	45	53	44	62	-	-	-	15	33	67	76	131	127
Morehead																69	147	221	164	283	261
Sub-total	255	221	268	272	306	315	314	325	290	396	314	346	-	-	-	267	450	538	514	638	604

Note: Table shows gross count of all students who started lessons.

TABLE 11

Total Number of Students Working at Each Grade Level in Each School as of March 29, 1968

Drill-and-Practice Mathematics

	Grade level									
Calif. schools	1	2	3	4	5	6	7	8	9	Total students
Grant					22	74				96
Garden Oaks						30	10	10		50
Peter Burnett							30	43	20	93
Walter Hays	67	71	64	78	94	72				446
Oak Knoll	29	37	52	1		1	26			146
Clifford	33	49	58	39	53	28				260
Fremont Hills			38		12	10				60
Sub-total	129	157	212	118	181	215	66	53	20	1151
Miss. schools										
Eva Gordon				38		29				67
Alpha Center	22					14				36
Kennedy						28				28
Universal	34			26		41				101
Westbrook				32		27				59
Taggart	25					29				54
Netterville		31								31
Otken			33	1	34	37				105
Hughes						29				29
Summit						30				30
Lillie M. Bryant					29					29
Franklin Center						68				68
Sub-total	81	31	33	97	63	332				637
Iowa										
Clinton Job Corps Ctr.	7	12	6	157	1	2				185
Ky. schools										
Brekenridge	30	36	30	33	27	31				187
Elliotsville			36	28	34	33				131
Morehead	34	31	27	76	32	73				273
Paintsville				81						81
Sub-total	64	67	93	218	93	137				672
Total	281	267	344	590	338	686	66	53	20	2645

exception of Peter Burnett, Garden Oaks, and Oak Knoll Junior High Schools. Even though the students are officially seventh, eighth, and ninth graders, they are working on lessons at the third-, fourth-, and fifth-grade levels.

Students in the Job Corps Center in Clinton, Iowa are high-school age, and older. These girls are attempting to learn a trade and to earn a high-school diploma at the same time. As shown in Table 11, there is considerable variation in their ability as indicated by the grade level to which they have been assigned. The majority of the students are working at the fourth-grade level.

The number of lessons given each day is graphed in Figure 4. Even though the data for three days were not available, the increase in the total number of arithmetic lessons, tests, reviews, and logic lessons over that of last quarter (86,630) is sizable. The total number for this reporting period is more than 119,960.

The percentage of students in California schools who have completed each concept block is shown in Table 12. Tables 12 through 14, respectively, show the percentage of students who have completed each concept block in Mississippi and Kentucky schools. The percentage for all schools is shown in Table 15.

The actual number of tests or lessons given on the last day of this reporting period is shown in Table 16. The distribution of students over concept blocks at each grade level is shown. This table emphasizes the demands for flexibility imposed on a system by a program which stresses individualization. Nearly every concept block at each grade level was sampled by some student during the day. Considering that the first 24 blocks at each grade level contain the planned content, this table shows that on March 29, more than 86 per cent of the total curriculum data base was sampled. The ability to have available for use the entire program at each grade level, together with a rapid system response to each student's input, has contributed significantly to the success of the program. When either of these two components are lacking, the system is less satisfactory from the teacher's point of view, as well as our own.

Table 17 presents the number of reviews sampled on March 29. As would be expected, the number of review blocks sampled is less than that of the number lessons. It is still clear from this table that it is necessary to have every review block available, since it is nearly impossible for a person to predict what will be needed on any given day.

2. Curriculum Revision

Revisions of the drill-and-practice curriculum were completed during this reporting period. Pretests and posttests for each block were revised to make them as nearly parallel as possible. Revision of the upper levels (levels 4 and 5) of each block to increase uniform difficulty was also completed.

TABLE 12

Percentage of Students Who Have Completed Each Concept Block in California Schools as of March 29, 1968 Drill-and-Practice Mathematics

	Grade					
Block	1	2	3	4	5	6
1	56	85	100	98	65	99
2	56	54	99	97	68	97
3	56	52	98	96	64	92
4	56	49	96	92	94	88
5	54	49	95	92	60	85
6	51	47	93	51	59	83
7	48	46	81	6	74	79
8	42	44	67	79	72	78
9	36	39	31	8	75	35
10	31	50	57	74	70	27
11	27	26	20	72	23	44
12	23	25	57	57	56	25
13	16	20	49	49	31	15
14	10	10	4	51	6	35
15	0	0	13	10	3	2
16	0	0	14	2	7	0
17	0	0	1	0	2	0
18	0	0	4	12	1	0
19	0	0	0	0	1	0
20	0	0	0	0	0	0
21	0	0	2	0	0	0
22	0	1	0	0	2	1
23	0	0	0	0	0	0
24	0	0	0	0	32	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	9	0
28	0	0	0	0	65	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0

TABLE 13

Percentage of Students Who Have Completed Each Concept Block in Mississippi Schools as of March 29, 1968

Drill-and-Practice Mathematics

	Grade					
Block	1	2	3	4	5	6
1	100	68	100	91	98	98
2	100	100	100	88	98	98
3	98	97	96	55	58	98
4	96	95	96	14	97	98
5	92	97	96	76	97	77
6	93	97	96	73	94	63
7	92	95	93	0	82	86
8	90	90	94	63	40	52
9	84	86	90	44	94	48
10	78	83	90	47	44	24
11	61	79	64	25	56	70
12	49	74	0	0	43	18
13	39	60	0	36	12	18
14	29	37	0	28	2	57
15	25	0	0	40	0	15
16	18	0	64	48	0	16
17	13	0	0	19	20	22
18	14	0	0	7	0	0
19	12	0	64	0	0	0
20	1	0	0	0	0	0
21	0	0	0	0	3	0
22	0	0	0	19	0	0
23	0	0	0	1	0	0
24	0	0	0	0	76	0
25	0	1	0	0	17	0
26	0	0	0	0	36	0
27	0	64	0	0	50	0
28	0	0	0	0	6	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0

TABLE 14

Percentage of Students Who Have Completed Each Concept Block in Kentucky Schools as of March 29, 1968

Drill-and-Practice Mathematics

Block	1	2	3	4	5	6
1	0	100	0	0	0	0
2	100	100	0	0	0	0
3	100	100	0	0	0	0
4	98	100	47	0	0	0
5	87	100	47	71	100	62
6	45	100	65	71	100	62
7	35	100	29	71	45	49
8	36	100	29	69	45	47
9	7	100	18	39	31	15
10	3	100	22	33	0	0
11	1	95	3	0	0	0
12	0	44	0	0	0	0
13	0	41	0	0	0	0
14	0	41	0	0	0	0
15	0	41	0	0	0	0
16	0	40	0	0	0	0
17	0	34	0	0	0	0
18	0	31	0	0	0	0
19	0	26	0	0	0	0
20	0	22	0	0	0	0
21	0	27	0	0	0	0
22	0	13	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0	0	0
25	0	0	0	0	0	0
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0

TABLE 15

Percentage of Students Who Have Completed Each Concept Block in All Schools as of March 29, 1968 Drill-and-Practice Mathematics

	Grade					
Block	1	2	3	4	5	6
1	75	80	88	82	74	95
2	80	64	87	76	77	94
3	77	61	85	66	61	92
4	79	58	85	59	95	90
5	74	58	84	68	76	78
6	62	57	84	47	71	69
7	57	61	67	17	72	79
8	57	59	64	60	55	59
9	41	48	32	22	72	40
10	38	59	48	50	48	22
11	28	51	18	45	28	56
12	25	36	34	29	42	18
13	19	31	28	27	19	15
14	15	22	3	15	4	41
15	9	9	8	14	2	9
16	6	9	24	20	3	9
17	4	8	1	5	8	13
18	5	7	3	7	0	0
19	4	6	16	0	0	0
20	0	4	0	0	0	0
21	0	3	1	0	0	0
22	0	2	0	5	1	0
23	0	0	0	0	0	0
24	0	0	0	0	94	0
25	0	6	0	0	63	0
26	0	0	0	0	73	0
27	0	89	0	0	71	0
28	0	0	0	0	51	0
29	0	0	0	0	0	0
30	0	0	0	0	0	0

TABLE 16

Number of Tests or Lessons Per Grade and Concept Given on March 29, 1968

Drill-and-Practice Mathematics

	Grade					
Block	1	2	3	4	5	6
1	5	11	18	10	3	10
2	0	2	9	1	8	0
3	1	3	1	0	20	1
4	2	8	3	21	3	1
5	15	5	14	3	3	28
6	27	2	10	78	3	2
7	12	5	58	2	41	19
8	23	2	18	5	7	20
9	29	8	20	28	16	42
10	25	6	13	6	19	20
11	13	17	54	19	10	9
12	12	43	26	16	21	31
13	9	10	23	19	51	74
14	10	14	5	1	6	85
15	14	16	8	3	1	20
16	5	5	28	25	19	19
17	7	2	12	7	9	33
18	7	4	29	14	5	4
19	2	3	0	0	1	0
20	15	11	0	0	0	0
21	2	12	4	0	2	0
22	8	16	0	4	3	4
23	8	0	0	2	0	3
24	4	0	0	0	9	0
25						
26	0	0	0	0	2	0
27	0	0	0	0	29	0

TABLE 17

Number of Reviews Per Grade and Concept Given on March 29, 1968

Drill-and-Practice Mathematics

	Block					
Block	1	2	3	4	5	6
1	7	0	17	4	5	2
2	16	4	15	2	7	3
3	17	2	8	1	19	13
4	4	0	13	0	1	3
5	6	0	10	3	5	39
6	10	9	5	3	2	17
7	6	3	4	1	3	9
8	5	0	4	2	17	40
9	3	5	8	0	9	42
10	1	10	2	0	1	18
11	2	5	17	3	0	12
12	12	0	0	0	22	2
13	22	7	0	4	0	8
14	2	2	0	1	0	9
15	0	1	0	5	0	1
16	0	0	3	19	0	1
17	0	1	0	2	2	5
18	0	5	0	0	0	0
19	0	9	0	0	0	0
20	0	9	0	0	0	0
21	0	2	0	0	0	0
22	0	0	0	3	0	0
23	0	0	0	0	0	2
24	0	0	0	0	7	0
25	0	0	0	0	1	0
26						
27	0	0	0	0	1	0

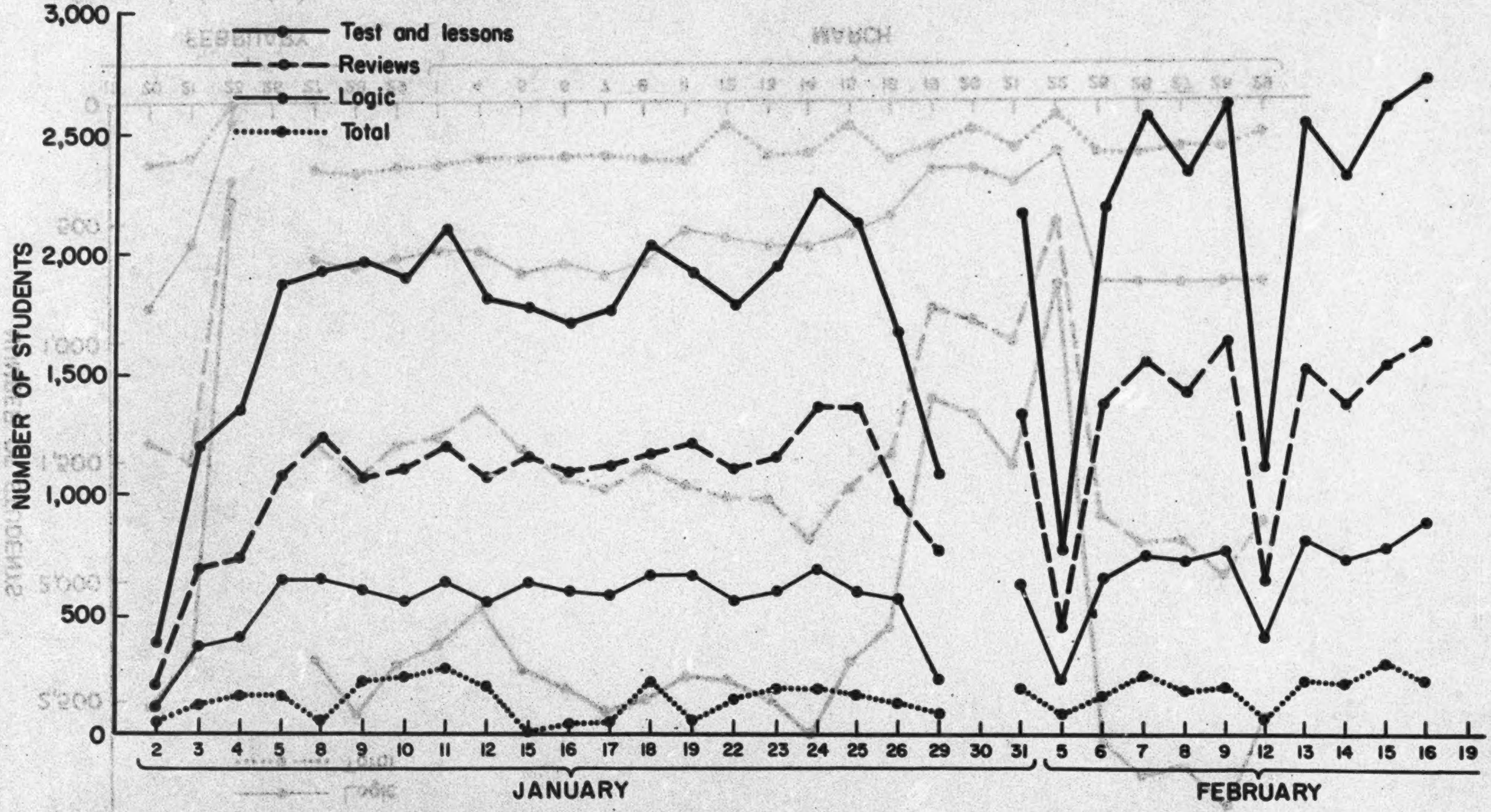

Figure 4. Number of Lessons Given Daily in Teletype Drill and Practice in Arithmetic

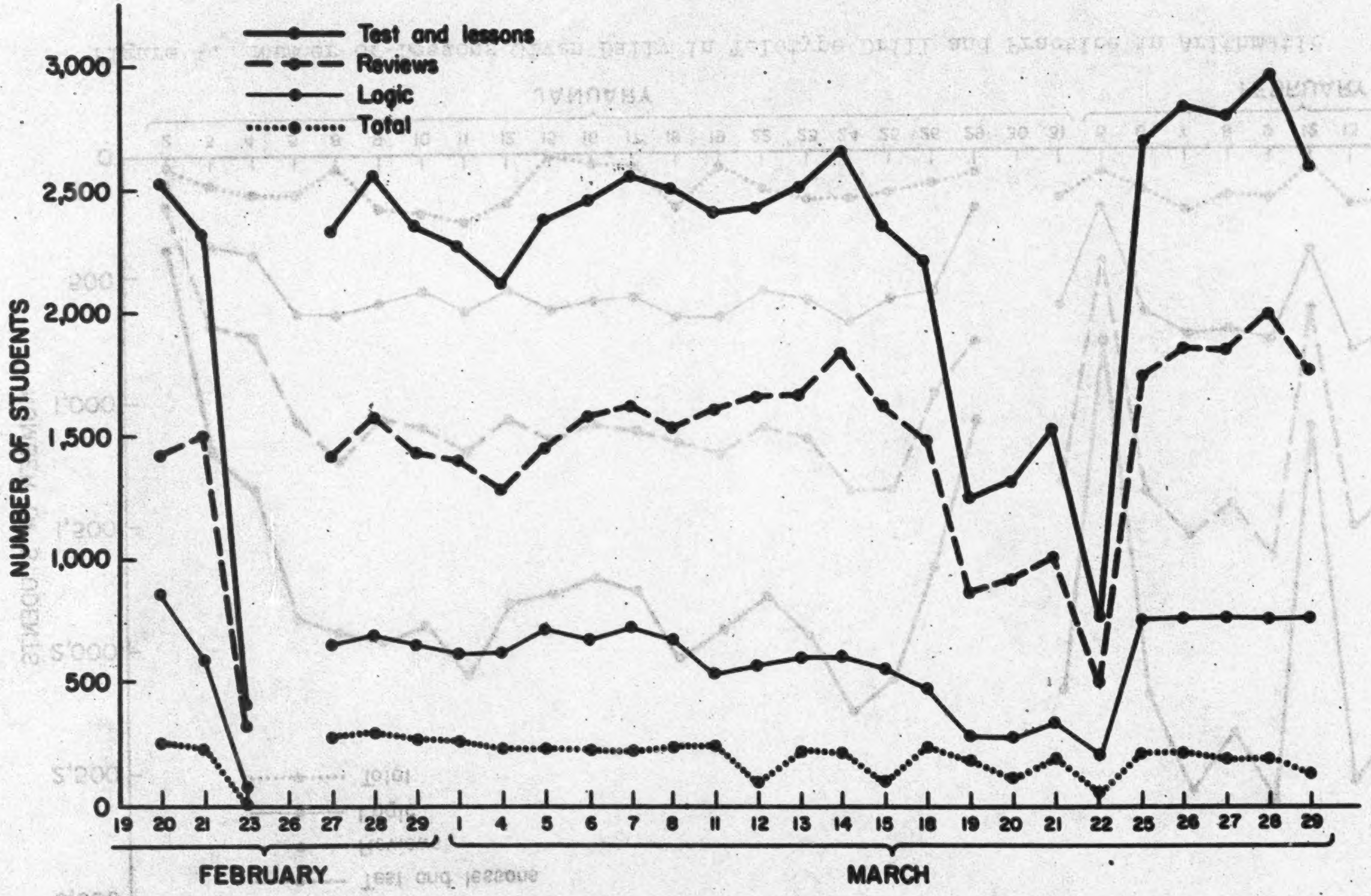

Figure 4 (cont'd)

3. Strands Program

California students began using addition, subtraction, and multiplication strands in place of their daily review lessons early in January. Students in grades 1 through 3 were started in addition and subtraction strands. Students in grades 4 and 5 were started in multiplication and subtraction strands. The subtraction strand will be replaced by the fraction strand as soon as it is ready early in April. Each student is given seven problems from each strand each day as a review lesson.

A description of the equivalence classes of problem types used in each of the first four strands is given in Table 18.

The number of students in each equivalence class in each strand is in Table 19.

TABLE 19

Number of Students in Each Equivalence
Class in Each Strand as of March 29, 1968
Drill-and-Practice Mathematics

	Equivalence class									
Strand	1	2	3	4	5	6	7	8	9	10
1 Addition	20	32	39	35	44	51	14	15	6	1
2 Subtraction	48	146	214	99	33	28	17	9	3	
3 Multiplication	24	104	148	63	1					

The first five equivalence classes of the multiplication strand, which consist of problems of the form

$$a \text{ x } b = \_\_, \quad a \text{ x } \_\_ = c, \quad \_\_ \text{ x } b = c, \text{ and } \underline{\overset{b}{\text{x } a}},$$

were established as the result of student performance on a specially constructed set of lessons included as part of the regular drill program. Problems up to 9 x 9 were rank ordered according to probability correct.

TABLE 18

Equivalence Classes of Problem Types in Addition, Subtraction, Multiplication, and Fraction Strands

Drill-and-Practice Mathematics

Strand 1 Column addition			
Class 1:	4 + 3	8 + 1	3 + 7
Class 2:	3 + 71	64 + 3	75 + 21
Class 3:	21 + 65	8 + 3	26 + 10
Class 4:	4 2 + 3	93 + 54	55 + 62
Class 5:	5 + 48	75 + 7	46 + 29
Class 6:	4 8 + 1	46 + 85	40 14 + 33
Class 7:	909 + 584	798 + 310	11 24 + 30
Class 8:	4 9 + 9	189 + 527	368 + 233
Class 9:	20 37 + 80	998 + 345	13 29 + 48
Class 10:	1757 + 4629	44 99 + 60	7562 + 5696
Class 11:	724 241 + 597	6999 + 6575	692 306 + 292

Strand 2 Column subtraction			
Class 1:	2 - 1	7 - 2	8 - 5
Class 2:	69 - 35	95 - 2	98 - 40
Class 3:	85 - 61	15 - 9	95 - 75
Class 4:	88 - 9	70 - 59	52 - 37
Class 5:	670 - 24	441 - 318	992 - 48
Class 6:	670 - 243	940 - 18	472 - 165
Class 7:	419 - 186	382 - 186	943 - 95
Class 8:	6231 - 2479	900 - 797	7413 - 938
Class 9:	6070 - 952	5801 - 3655	6900 - 4114
Class 10:	5007 - 3808	7061 - 5215	2808 - 769

TABLE 18 (cont'd)

Strand 3 multiplication

Class 6:	10 x 6	30 x 2	80 x 1
Class 7:	100 x 7	200 x 6	500 x 1
Class 8:	30 x 4	50 x 5	90 x 2
Class 9:	200 x 7	400 x 3	900 x 2
Class 10:	40 x 7	60 x 3	90 x 8
Class 11:	600 x 3	400 x 7	500 x 9
Class 12:	60 x 8	70 x 9	90 x 6
Class 13:	700 x 5	400 x 8	900 x 7
Class 14:	40 x 30	70 x 20	90 x 20
Class 15:	30 x 80	60 x 50	90 x 80
Class 16:	60 x 70	80 x 90	40 x 80
Class 17:	200 x 40	500 x 30	700 x 70
Class 18:	200 x 30	500 x 70	900 x 90
Class 19:	300 x 60	700 x 40	900 x 70
Class 20:	12 x 6	11 x 9	26 x 2
Class 21:	120 x 2	380 x 1	110 x 8
Class 22:	2 x 606 =	3 x 102 =	6 x 201 =
Class 23:	22 x 7	25 x 4	49 x 2
Class 24:	2 x 12 =	2 x 66 =	4 x 11 =
Class 25:	340 x 3	520 x 4	720 x 7
Class 26:	2 x 904 =	5 x 402 =	4 x 505 =
Class 27:	44 x 7	89 x 5	93 x 8
Class 28:	260 x 3	890 x 5	950 x 9
Class 29:	5 x 608 =	8 x 205 =	9 x 508 =
Class 30:	54 x 20	33 x 40	77 x 30
Class 31:	46 x 40	85 x 70	95 x 90
Class 32:	97 x 4	67 x 9	46 x 8
Class 33:	98 x 30	47 x 90	74 x 80
Class 34:	890 x 4	480 x 9	660 x 8

TABLE 18 (cont'd)

Strand 3 multiplication

Class 35:	6 x 709 =	8 x 303 =	9 x 403 =
Class 36:	323 x 2	878 x 1	222 x 6
Class 37:	22 x 55	63 x 21	88 x 11
Class 38:	230 x 21	620 x 12	110 x 99
Class 39:	345 x 5	272 x 7	594 x 2
Class 40:	33 x 54	77 x 23	35 x 35
Class 41:	5 x 24 =	6 x 66 =	7 x 27 =
Class 42:	323 x 21	613 x 12	666 x 22
Class 43:	348 x 7	845 x 7	959 x 9
Class 44:	45 x 67	89 x 58	55 x 79
Class 45:	4 x 76 =	8 x 25 =	9 x 59 =
Class 46:	550 x 25	340 x 35	750 x 23
Class 47:	450 x 67	980 x 58	590 x 98
Class 48:	897 x 4	839 x 6	748 x 9
Class 49:	89 x 63	97 x 64	76 x 89
Class 50:	7 x 96 =	8 x 94 =	9 x 73 =
Class 51:	370 x 96	980 x 53	780 x 64
Class 52:	345 x 35	957 x 22	747 x 23
Class 53:	585 x 78	835 x 78	689 x 58
Class 54:	789 x 46	987 x 64	837 x 96

TABLE 18 (cont'd)

Strand 4 fractions

Class 1:	Look at these letters x x x x How many letters are there? ___ 1/4 of 4 = ___ 1/2 of 4 = ___	Number of letters $2 \le n \le 24$ Begin with: 1/2, 1/3, 1/4, 1/5, 1/6, 1/8, 1/10 then, 2/3, 2/4, 3/4, etc.
Class 2:	Number and denominator What is the $\frac{N}{D}$ of each of these fractions? 2/3, etc. ___	
Class 3:	Type < or = or > 1/3 __ 2/3 2/4 __ 1/2 8/10 __ 8/9 2/5 __ 3/5, etc.	
Class 4:	Add or subtract 1/2 + 2/5 = __ /5 2/3 + 1/3 = __ /3 = __	All like denominators Some simplifying
Class 5:	Complete each problem 2/4 = __ /2 1/3 = __ /6, etc. 2/5 =	Begin with different denominators which are different by a factor of 2, then 3, 4, etc.

TABLE 18 (cont'd)

Class 6: Add or subtract

1/2 + 1/4 = __ /4
1/2 - 1/6 = __ /6
= __ /3
1/3 + 1/2 = __ /6 + __ /6
= __ /6, etc., including
3 ± 1/2 = __ /2 ± 1/2
= __ /2
= __ __ /2

One denominator a multiple of the other
Problems may have 2 steps

Class 7: Complete each problem

1 1/2 = __ /2
5/2 = __ __ /2, etc.
13/2 = __ 1/2

Class 8: Type < or = or >

1 1/2 __ 3/2
3/4 __ 2 1/4, etc.

Class 9: Add or subtract

1 1/3 + 2 1/3 = (1 + __) + 1/3 + __ /3)
= __ + __ /3
= 3 __ /3
2 3/4 - 1 1/4 = (2 - __) + (3/4 - __/4)
= __ + __ /4
= 1 __ /4
= 1 __ /2
2 1/5 + 3 1/4 = (__ + 3) + (1/5 + __ /4)
= __ + (__ /20 + __ /20)
= 5 + __ /20
= 5 __ /20

TABLE 18 (cont'd)

Class 10: Complete each problem
5/8 = __ /24
3/5 = 12/ __
n/4 = 3/12
n = __,etc.
5/4 = 4/4 + __ /4
= __ + 1/4
= __ 1/4, etc.

Class 11: Multiply
2 x 1/3 = __ /3
1/4 x 3 = __ /4
1/3 x 2/3 = __ /9
3/5 x 2/6 = __ /30
= __ /15
2 1/4 x 3 1/4 = (2 + 1/4) x (3 + __ /4)
= 2 x (3 + __ /4) + 1/4 x (3 + __ /4)
or as a mixed number (see 12)

Class 12: Divide
2 divided by 1/3 = 2 x __ / __
= __ / __
=
1/4 divided by 3 = 1/4 x __ / __
= __ /12
1/3 divided by 1/2 = 1/3 x __ / __
= __ / __
1 1/2 divided by 2 1/3 = 3/2 divided by __ /3
= 3/2 x __ / __
= __ /14,
etc.

Class 13: Mixed
Combination of problems from sections 9, 10, 11, 12

4. Problem Solving

This program was developed to examine the factors involved in teaching fifth graders how to use the computer as a desk calculator to solve multistep word problems. It was also designed to permit investigation of variables which might contribute to problem difficulty.

In all, 27 fifth-grade students from the six-year longitudinal study group served as subjects for the pilot edition of the program. Sixty-eight word problems were prepared.

Figure 5 presents the last two problems of the pilot program. As can be seen, the program ran on a modified version of the logic program. "Givens" replaced "premises" of the logic program. The "givens" were the numbers shown in the problem statement, listed in order of appearance.

In place of giving abbreviations for rules of logic, students gave operator commands such as add (A), subtract (S), multiply (M), divide (Q), enter a constant (E), or the answer is on line N(NX).

As in the logic program, students were free to proceed independently to find solutions.

Data analysis was begun using as variables in a linear-regression program the total number of words in each problem, the minimum number of operations required for solution, and the minimum number of different operations required.

5. Performance as a Function of Problem Type

In order to examine differences in performance as a function of problem type at each grade level, the average probability correct for several types of problems for each grade was determined. Data were obtained from the pretests for blocks 3-8 in Grade 1, blocks 1-5 and 7-9 in Grade 2, blocks 1-8 and 10 in Grade 3, blocks 1-5 in Grade 4, and blocks 1-3 in Grade 5. The average probability correct for some of the problem types examined is shown in Table 20 (problem types appearing at only one point in the total curriculum are not presented). These averages are based upon performance of from 20-60 *Ss* with a given problem type occurring from 1-15 times in a given block. For a given grade and problem type, the successive probabilities are for successive blocks in the curriculum containing that problem type with the actual block number in parentheses.

In the description of problem types in Table 20 each digit is represented by an initial letter of the alphabet. For horizontal problems the digit or digits underlined indicate the position of the blank when the problem was presented to the student. For addition problems the probability correct did not differ as a function of the number of digits in each addend as long as the number of digits in the response were equivalent. Therefore, these problems were combined to form a single problem type (e.g., the second problem type in Table 20).

```
601.103

COMMITTEE MEMBERS BOUGHT 3 JARS OF CANDY
WITH 14 OUNCES IN EACH JAR, AND 2 BOXES OF CANDY
WITH 27 OUNCES IN EACH BOX.  THEY PUT THE CANDY
INTO BAGS THAT CONTAINED 4 OUNCES EACH.
HOW MANY BAGS OF CANDY DID THEY FILL...
G              (1)  3
G              (2)  14
G              (3)  2
G              (4)  27
G              (5)  4
1.2M           (6)  42
3.4M           (7)  54
6.7A           (8)  96
8.5Q           (9)  24
9X
CORRECT.
```

```
601.104

THIS IS THE LAST WORD PROBLEMSS

3 CLASSES OF 32 PUPILS EACH, 1 CLASS OF 34 PUPILS,
4 TEACHERS, AND 7 PARENTS TOOK A TRIP ON 3 BUSES.
EACH BUS TOOK THE SAME NUMBER OF RIDERS.
HOW MANY RIDERS WERE ON EACH BUS...
G              (1)  3
G              (2)  32
G              (3)  1
G              (4)  34
G              (5)  4
G              (6)  7
1.2M           (7)  96
4.5A           (8)  38
4.7A           (9)  130
6.9A           (10) 137
5.10A          (11) 141
11.1Q          (12) 47
12X
CORRECT.
```

Figure 5. Last Two Problems in the Problem-Solving Pilot Program, Drill-and-Practice Mathematics

TABLE 20

Average Probability Correct as a Function of Problem Structure Drill-and-Practice Mathematics

Horizontal Addition

Problem	Carry or borrow	Grade	Probability correct
a + b = c	0	1	.95*
		2	.95 (1)** .95 (4) .92 (5) .94 (7)
		3	.94 (1) .95 (2)
		4	.95 (1)
a + b = ef ab + c = ef a + bc = ef	0	2	.38 (4) .72 (7) .69 (9)
		3	.69 (1) .75 (2)
		4	.73 (1)
		5	.61 (1)
ab + cd = ef	1	3	.55 (1) .80 (2)
		4	.62 (1)
		5	.67 (1) .68 (3)
a + b + c = de	1	2	.36 (7) .63 (9)
		4	.59 (1)
		5	.85 (3)
ab + c = de a + c = de a + c = d		1	.87*
		2	.82 (1) .90 (4) .83 (7) .72 (9)
		3	.74 (1) .79 (2)
		4	.86 (1)
		5	.82 (1)
a + bc = de		3	.31 (1) .41 (2)
		4	.36 (1)
		5	.53 (1)

*First-grade data is an average of Blocks 3-8.

**Numbers in parenthesis indicate block number.

TABLE 20 (cont'd)

Problem	Carry or borrow	Grade	Probability correct			
a + b = cd a + bc = de a + b = c		1	.82			
		2	.82 (1)	.84 (5)	.66 (7)	.62 (9)
		3	.68 (1)	.79 (2)		
		4	.76 (1)			
		5	.81 (1)			
ab + cd = ef	0	4	.46 (1)			
		5	.66 (1)	.39 (3)		
	1	3	.19 (2)			
		5	.47 (1)	.31 (3)		
Horizontal Subtraction						
a - b = c		2	.94 (2)	.84 (5)	.89 (8)	.93 (9)
		3	.88 (1)	.93 (3)		
		4	.94 (2)			
ab - c = de	0	3	.56 (1)	.70 (3)		
		4	.80 (2)			
		5	.78 (2)			
	1	3	.33 (1)	.62 (3)		
		4	.44 (2)			
		5	.60 (3)			
a - b = c		2	.84 (2)	.83 (5)	.71 (8)	.91 (9)
		3	.81 (3)			
		5	.91 (2)			
ab - c = de		3	.66 (1)	.65 (3)		
		4	.78 (2)			
		5	.85 (2)			
a - b = c		2	.32 (2)			
		3	.52 (3)			
		5	.70 (2)			

TABLE 20 (cont'd)

Problem	Carry or borrow	Grade	Probability correct
$\underline{a} - b = c$		2	.32 (2)
		3	.52 (3)
		5	.70 (2)
$\underline{ab} - c = de$		2	.42 (8) .66 (9)
		3	.28 (1) .39 (3)
		4	.33 (4)
		5	.44 (2) .66 (3)
		Vertical Addition	
$\begin{array}{r} a \\ \underline{+\ b} \\ c \end{array}$		1	.95
		2	.92 (3) .97 (4) .91 (5) .94 (7) .91 (9)
		3	.95 (2)
		4	.96 (1)
$\begin{array}{r} a \\ \underline{+\ b} \\ c\ d \end{array}$		2	.60 (4) .66 (5) .57 (7) .52 (9)
		3	.32 (2) .62 (4)
		4	.37 (1)
$\begin{array}{r} ab \\ \underline{cd} \end{array}$ $\begin{array}{r} ab \\ \underline{c} \end{array}$ $\begin{array}{r} a \\ \underline{bc} \end{array}$	0	3	.69 (2) .93 (4) .94 (6) .87 (8) .84 (10)
		4	.72 (1) .95 (4) .92 (5)
		5	.66 (1) .81 (3)
	1	3	.45 (2) .74 (4) .81 (6) .77 (8) .81 (10)
		4	.62 (1) .87 (4) .81 (5)
		5	.62 (1) .82 (3)
	2	4	.71 (4) .80 (5)
$\begin{array}{r} abc \\ \underline{+de} \end{array}$ $\begin{array}{r} abc \\ \underline{+def} \end{array}$	0	3	.93 (4) .90 (6) .86 (8)
		4	.95 (4) .90 (5)
	1	3	.69 (4) .82 (6) .64 (8) .76 (10)
		4	.84 (4) .77 (5)
		5	.79 (3)
	2	3	.66 (6)
		4	.84 (4) .77 (5)
		5	.64 (3)

TABLE 20 (cont'd)

Problem	Carry or borrow	Grade	Probability correct				
a b +c	0	3	.80 (6)	.97 (8)			
	1	3	.31 (10)				
ab cd +ef	0	3	.87 (4)	.84 (6)	.87 (8)		
	1	3	.58 (4)	.69 (6)	.73 (8)	.71 (10)	
		4	.46 (1)				
	2	3	.53 (6)	.70 (10)			
Vertical Subtraction							
a -b		2	.93 (3)	.88 (5)	.91 (8)	.90 (9)	
		3	.90 (3)				
		4	.90 (2)				
ab -c	0	3	.81 (3)	.90 (5)	.88 (7)	.83 (8)	.79 (10)
		4	.70 (2)	.86 (3)	.82 (5)		
		5	.70 (2)				
	1	3	.42 (3)	.35 (5)	.69 (7)	.75 (8)	.72 (10)
		4	.53 (2)	.74 (3)	.78 (5)		
		5	.61 (2)				
ab -cd	0	3	.75 (3)	.82 (5)	.86 (7)	.80 (8)	.86 (10)
		4	.85 (2)	.94 (3)	.82 (5)		
		5	.83 (2)				
	1	3	.38 (5)	.53 (7)	.62 (8)	.68 (10)	
		4	.76 (3)	.70 (5)			
		5	.54 (2)	.73 (3)			
abc -de	0	3	.86 (5)				
	1	3	.47 (5)	.61 (10)			
		4	.51 (2)				

TABLE 20 (cont'd)

Problem	Carry or borrow	Grade	Probability correct
abc -def	0	3	.84 (5)
		4	.91 (3)
	1	3	.45 (5) .66 (10)
		4	.58 (5)
		5	.66 (3)
	2	4	.46 (3)
abcd -efgh	1	4	.58 (5)
	2	4	.44 (5)
		5	.43 (3)

D. Logic and Algebra Program

1. The First-year Program

Lesson writing and programming. The last six lessons in sentential logic and algebra were completed, coded and debugged. This completes the program as planned. The programming was also completed with all known bugs removed.

Student progress. Five of the 170 students have now completed the first-year materials and have started on the tenth lesson of the second-year materials. Another 22 students are past the beginning of lesson 30 (octal numbering). It is anticipated that most likely the first-year materials will be completed by the end of May.

Audio link. Most programmed instruction is entirely tutorial: the program gives instructions and then asks fixed questions with fixed answers. More desired is a dialogue in which the student may make unprogrammed communications to the program. The logic program is already partially a dialogue in that the student response in derivations is not coded, rather the student communicates with the machine in the language of the rules of derivation. The machine responds by carrying out the student's correctly given commands. The next step in the program then is to direct investigation to extend the use of dialogue.

We propose to supply the student who is having difficulty with a machine dialogue covering possible strategies of proof. Our first step is to learn what questions the students would like to ask and what answers are instructive. To do this in a way that simulates student-machine dialogue, we have set up one of the teletypes in Walter Hays School (where we have both first-year and second-year logic students) with a headphone telephone connected with the laboratory on the Stanford campus. A slave teletype monitors the student's teletype, and an experienced logic teacher watches the monitor and answers questions from the student. This is usually done with leading questions from the teacher. The entire audio dialogue is being tape recorded and transcribed for subsequent analysis.

2. The Second-year Program

Lesson writing and coding. To motivate the students and to give them an appreciation of the axiom system which they are learning, additional lessons were written and inserted between the existing lessons dealing with the major theorems.

Teletype room. Students participating in the second-year algebra program also participated in the audio link described above.

3. The Third-year Program

The program is still in the planning and lesson writing stages. The logic has been extended by introducing the biconditional. There are several lessons on the use of the biconditional, including the introduction of new logical rules which enable the students to work with the new connective. In conjunction with the section on biconditionals, there is also a lesson on definitions, which is given in a biconditional form.

For the algebra part of the program, lessons have been written which include all the theorems that enable the student to solve linear equations in a single unknown. Lessons have also been written which contain a large selection of word problems solvable by this type of equation. In addition, there are also theorems which enable the student to determine the range of the unknown in any linear inequality.

A geometry booklet is being prepared which will be used with the algebra. A preliminary draft of the section of the booklet dealing with the real number line and representations of inequalities thereon has been completed.

4. Data Analysis

A thorough analysis of the 1966-67 logic and algebra performance data is now in progress. During the period covered by this report, seven major computer programs have been developed. These programs: (a) collate and sort the performance data; (b) determine proof isomorphisms; (c) list and report results; and (d) merge new performance data. Additionally, work has begun on programs to determine sequential statistics and "protocol" isomorphisms.

Several standard statistical analyses are being exploited in this connection. For example, regression analysis is being used to examine the structural variables that predict performance. (The format of the logic and algebra curriculum does not permit "wrong" answers; hence, probabilities of correctness. One dependent variable considered then is the response or problem latency.)

E. Dial-a-Drill Program

1. Student Enrollment

By January 3, the dial-a-drill roster had grown to fourteen students. Four students were at or below second-grade level, one was at the third-grade level, and nine were at or above the fourth-grade level.

2. Curriculum Material

Students up to and including the second-grade level were given addition and subtraction problems. Third graders were given problems from these two strands, plus problems from the multiplication strand. Fourth, fifth, and sixth graders had a fourth strand, i.e., division, added to their curriculum. Table 21 illustrates each of the strands and defines the equivalence classes within each.

A new strand was introduced on February 19. Fractions, as outlined in Table 22, began running for the fourth, fifth, and sixth graders. Eighteen new vocabulary words were added to accommodate this strand. Answers were accepted in any form, other than mixed numbers, if correct. Since measure of difficulty was poorly defined among the

TABLE 21

Addition, Subtraction, and Multiplication Strands

Dial-a-Drill Program

Equivalence Class	Addition	
	Type	Limitations
1	$m + n = \underline{\quad}$	$0 \leq m + n \leq 6$
2	$\underline{\quad} + n = k$ $m + \underline{\quad} = k$	$0 \leq m + n \leq 6$
3	$m + n = \underline{\quad}$	$4 \leq m + n \leq 10$
4	$\underline{\quad} + n = k$ $m + \underline{\quad} = k$	$4 \leq m + n \leq 10$
5	All 3 types: i.e., $m + n = \underline{\quad}$ $m + \underline{\quad} = k$ $\underline{\quad} + n = k$	$7 \leq m + n \leq 13$
6	All 3 types	$10 \leq m + n \leq 17$
7	All 3 types	$13 \leq m + n \leq 20$
8	$m + n = \underline{\quad}$	$19 \leq ab + cd \leq 29$ $b + d \leq 9$ a or c may be 0
9	All 3 types	$19 \leq ab + c \leq 29$ $b + c \leq 9$
10	All 3 types	$30 \leq ab + c \leq 49$ $b + c \leq 9$
11	$m + n = \underline{\quad}$	$200 \leq abd + def \leq 1900$ $b = c = e = f = 0$
12	$m + n = \underline{\quad}$	$30 \leq ab + cd \leq 49$ $b + d \leq 9$
13	$m + n = \underline{\quad}$	$50 \leq ab + cd \leq 99$ $b + d \leq 9$
14	$m + n = \underline{\quad}$	$19 \leq ab + c \leq 99$ $b + c > 9$

TABLE 21 (cont'd)

Equivalence Class	Addition	
	Type	Limitations
15	m + n =	$110 \leq abc + de \leq 999$ $e = o$ $b + d \leq 9$
16	m + n = __	$110 \leq abc + de \leq 999$ $c + e \leq 9$ $b + d \leq 9$
17	m + n = __	$31 \leq ab + cd \leq 99$ $b + d > 9$
18	m + n = __	$100 \leq ab + cd \leq 198$ $b + d > 9$ $a + c > 8$
19	m + n = __	$110 \leq abc + de \leq 999$ $b + d < 9$ $c + e > 9$
20	m + n = __	$110 \leq abc + de \leq 1098$ $b + d > 8$ $c + e > 9$

Equivalence Class	Subtraction	
	Type	Limitations
1	m - n = __	$0 \leq n \leq m \leq 6$
2	m - __ = p	$0 \leq n \leq m \leq 6$
3	m - n = __	$4 \leq m \leq 10, n \leq m$
4	__ - n = p	$0 \leq n \leq m \leq 6$
5	m - __ = p	$4 \leq m \leq 10, n \leq m$
6	m - n = __	$7 \leq m \leq 13, n \leq m$
7	__ - n = p	$4 \leq m \leq 10, n \leq m$
8	m - __ = p	$7 \leq m \leq 13, n \leq m$

TABLE 21 (cont'd)

Equivalence Class	Subtraction	
	Type	Limitations
9	$\underline{\quad} - n = p$	$7 \le m \le 13, n \le m$
10	All 3 types: i.e., $m - n = \underline{\quad}$ $m - \underline{\quad} = p$ $\underline{\quad} - n = p$	$10 \le m \le 17, n \le m$
11	All 3 types	$15 \le m \le 20, n \le 9$
12	$m - n = \underline{\quad}$	$20 \le m \le 99, n \le 10$
13	All 3 types	$20 \le m \le 99, n \le 10$
14	$m - n = \underline{\quad}$	$10 \le m \le 99$ $n = 10 \times a$
15	All 3 types	$10 \le m \le 99$ $n = 10 \times a$
16	$ab - cd =$	$20 \le ab \le 99, d \le b$ $c < a$
17	$ab - cd = \underline{\quad}$ $ab - \underline{\quad} = ef$ $\underline{\quad} - cd = ef$	$20 \le ab \le 99, c < a$ $d \le b$
18	$abc - de = \underline{\quad}$	$110 \le abc \le 999$ $d \le b, e \le c, d \ne 0$
19	$abc - de = \underline{\quad}$ $abd - \underline{\quad} = fg$ $\underline{\quad} - de = fg$	$110 \le abc \le 999$ $d \le b$ $e \le c$ $d \ne 0$
20	$ab - cd = \underline{\quad}$	$20 \le ab \le 98$ $d > b, a > c$
21	$ab - cd = \underline{\quad}$ $ab - \underline{\quad} = ef$ $\underline{\quad} - cd = ef$	$20 \le ab \le 98$ $d > b,$ $c < a$

TABLE 21 (cont'd)

Equivalence Class	Multiplication	
	Type	Limitations
1	$a \times b = \_\_$	$0 \leq a \times b \leq 10$
2	All 3 types: i.e., $a \times b = \_\_$ $a \times \_ = c$ (if $a = c, \neq 0$) $\_ \times b = c$ (if $b = c, \neq 0$)	 $0 \leq a \times b \leq 10$
3	$a \times b = \_\_$	$8 \leq a \times b \leq 30$
4	All 3 types	$8 \leq a \times b \leq 30$
5	$a \times b = \_\_$	$21 \leq a \times b \leq 81$
6	All 3 types	$21 \leq a \times b \leq 81$
7	$a \times bc = \_\_$	$0 \leq a \times b \leq 20$ $b \neq 0, c = 0$
8	All 3 types of $a \times bc = def$	$0 \leq a \times b \leq 20$ $b \neq 0, c = 0$
9	$a \times bc = \_\_$	$20 \leq a \times b \leq 81$ $b \neq 0, c = 0$
10	All 3 types of $a \times bc = def$	$20 \leq a \times b \leq 81$ $b \neq 0, c = 0$
11	$ab \times cd = \_\_$	$b = d = 0$ $1 \leq a, c \leq 9$
12	All 3 types of $ab \times cd = efgh$	$1 \leq a, c \leq 9$ $b = d = 0$
13	$abc \times d = \_\_$	$b = c = 0$ $1 \leq a, d \leq 9$
14	All 3 types of $abc \times d = efgh$	$b = c = 0$ $1 \leq a, d \leq 9$
15	$a \times bc = \_\_$	$1 \leq a, b, c \leq 9$
16	$ab \times cd = \_\_$	$b = 0$ $10 \leq cd \leq 99$

TABLE 21 (cont'd)

Equivalence Class	Division	
	Type	Limitations
1	$c / a = \_\_$	$0 \leq c \leq 10$, $a \neq 0$
2	All 3 types i.e., $c / a = \_\_$ $c / \_\_ = b$ $\_\_ / a = b$	$0 \leq c \leq 10$, $a \neq 0$
3	$c / a = \_\_$	$8 \leq c \leq 30$, $a \neq 0$
4	All 3 types	$8 \leq c \leq 30$, $a \neq 0$
5	$c / a = \_\_$	$21 \leq c \leq 81$, $a \geq 3$
6	All 3 types	$21 \leq c \leq 81$, $a \geq 3$
7	$def / ab = \_\_$ $def / c = \_\_$	$0 \leq def \leq 200$ $a \neq 0$, $b = 0$
8	$c / a = \_\_$ $c / \_\_ = b$ $\_\_ / a = b$	$a = 9$, 11, or 12 and / or $b = 9$, 11 or 12
9	$def / a = \_\_$	$2 \leq def \leq 888$ d, e, and f even no's. $a = 2$
10	$def / a = \_\_$	$2 \leq def \leq 898$ d, f even no's $a = 2$
11	$def / a = \_\_$	$2 \leq def \leq 998$ d and/or e even no's $a = 2$
12	All 3 types of $def / ab = c$	$0 \leq def \leq 200$ $a \neq 0$, $b = 0$
13	$def / ab = \_\_$ $def / c = \_\_$	$200 \leq def \leq 810$ $a \neq 0$, $b = 0$, $f = 0$
14	$def / ab = \_\_$	$10 \leq def \leq 480$ $b = 0$

TABLE 21 (cont'd)

Equivalence Class	Division	
	Type	Limitations
15	All 3 forms of def / ab = c	$200 \leq def \leq 810$ $a \neq, b = 0$
16	cdef / g cdef / gh cdef / ghi cdef / ghij	$d = e = f = h = i = j = 0$ $a = 1$ or $a = c$
17	cdefg / hi cdefg / hij cdefg / hijk cdefg / hijkl	$d = e = f = g = i = j = k = l = 0$ $a = 1$ or $a = c$

TABLE 22

Fraction Strand, Dial-a-Drill Program

Equivalence Class	Fraction Strand		
	Form	Limitations	
1	m/n = ?/k	reduce or expand only to up to 9th's	
2	m/n = k/?	reduce or expand only go up to 9th's	
3	1/n of m = __	$2 \leq n \leq 4$, $2 \leq m \leq 20$ m/n is integer	
4	1/n of m = __	$4 \leq n \leq 8$, $12 \leq m \leq 32$ m/n is an integer	
5	n/m of m = __	$1 \leq n \leq 8$; $2 \leq m \leq 9$ $n \leq m$	
6	$\frac{n}{m} + \frac{k}{m}$ = __	$2 \leq n + k \leq 9$, $1 \leq m \leq 9$ $1 \leq n, k$ $\frac{n}{m} + \frac{k}{m} \leq 1$	
7	$\frac{n}{m} + \frac{k}{t}$ = __	$2 \leq n, k \leq 9$; $2 \leq m, t \leq 9$ $\frac{n}{m} + \frac{k}{t} \leq 1$	
8	$\frac{n}{m} - \frac{k}{m}$ = __	Same limits as t, $k < n$	
9	$\frac{n}{m} - \frac{k}{t}$ = __	Same limits as 7, $\frac{n}{m} > \frac{k}{t}$	
10	n/m x k/m	$2 \leq m \leq 5$, $n \times k \leq 10$	The term "over" will be used here. (i.e.,"2/15" will be read "2 over 15")
11	n/m x k/m	$4 \leq m \leq 7$, $10 \leq n \times k \leq 30$	
12	n/m x k/m	$6 \leq m \leq 9$, $24 \leq n \times k \leq 81$	
13	$\frac{n}{m}$ x k/t	Same restrictions as No. 10	The term "over" will be used here. (i.e.,"2/15" will be read "2 over 15")
14	$\frac{n}{m}$ x k/t	Same restrictions as No. 11	
15	n/m x k/t	Same restrictions as No. 12	

TABLE 22 (cont'd)

Begin with one problem from each of levels

1, 2, 3, 6, 8, 10

"Intuitive difficulty" lay-out is

1	6	8	10
2	7	9	11
3			13 ___?
4			12 ___?
5			14
			15

various types of problems, students began with one problem from each of classes 1, 2, 3, 6, 8, and 10.

3. Evaluative Procedures

On February 19, several changes were instituted. Until this time, if a problem was answered correctly after the first or second statement of the question, it was considered correct. Beginning February 19, a problem was correct only if the response was correct on the first trial; half credit was given for a correct answer on the second trial; and no credit was given for an incorrect response or no response.

Also beginning February 19, students were broken up into two "matched" groups for the addition and subtraction strands. One group continued to receive problems in blocks of 10 and branched according to previous criteria. The other group's performance was evaluated after each problem. A correct response moved the student up one level, a correct answer on the second trial kept him at the same level, an incorrect response dropped him one level. After four weeks of running in this manner, the two groups were switched.

4. Data Analysis

Figure 6 shows the progress of a typical student who is assessed after completing 10 questions in an operation. In this case, levels 1 to 5 are shown as successfully completed, but progress is slower in levels 6 to 10 which are repeated once or twice. Level 11 is failed, giving a return to 10. Figure 7 shows the performance curves for several students. There is a discernable pattern of repeats and failures at levels 4, 7, and 10, which these students have found particularly difficult.

Figures 6 and 7 represent the original scoring scheme (9, 10 advance, 0-6 fail) where equal credit was given for a correct answer on the first or second attempt. Figure 8 compares the two subsequent scoring systems. The upper line shows assessment after each problem (a correct response on the first attempt advances the student, if a correct response is given on the second attempt the same level is repeated, otherwise the next lower level is selected). The lower line indicates 10 questions per level, with half credit for correct responses on the second attempt. The students compared here had shown signs of settling in the region of level 12 on the original scoring system. Although the range is comparatively great when changing levels on each problem, the mean is in the 15-16 area. On 10 problems per level, the other student has moved to the 10-12 range.

The effect of raising the average level by adopting the "one problem" scheme, and depressing it by the half-credit change, was notable in nearly all the students.

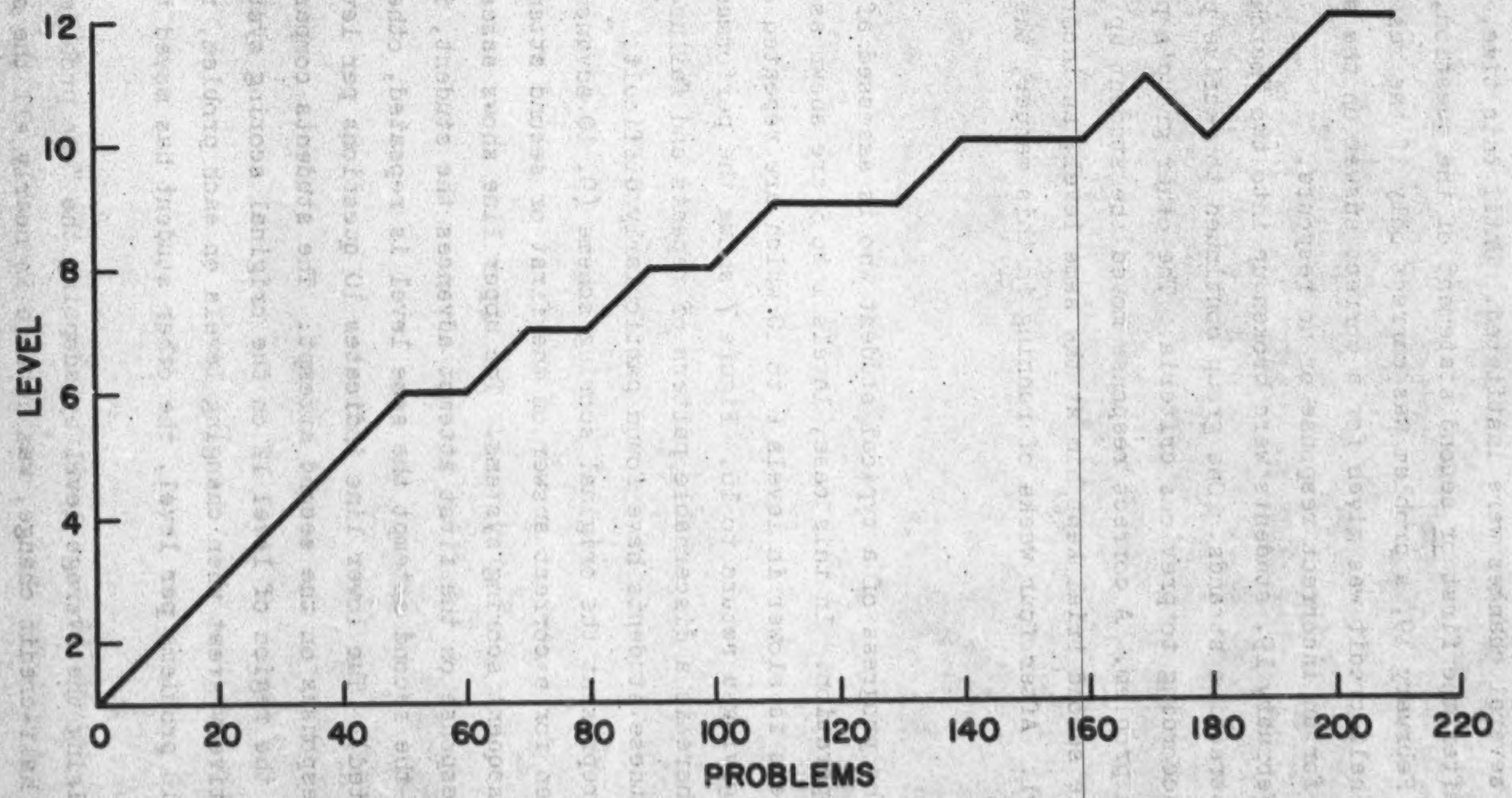

Figure 6. Performance Curves on Student 1 in the Addition Block, Dial-a-Drill Program

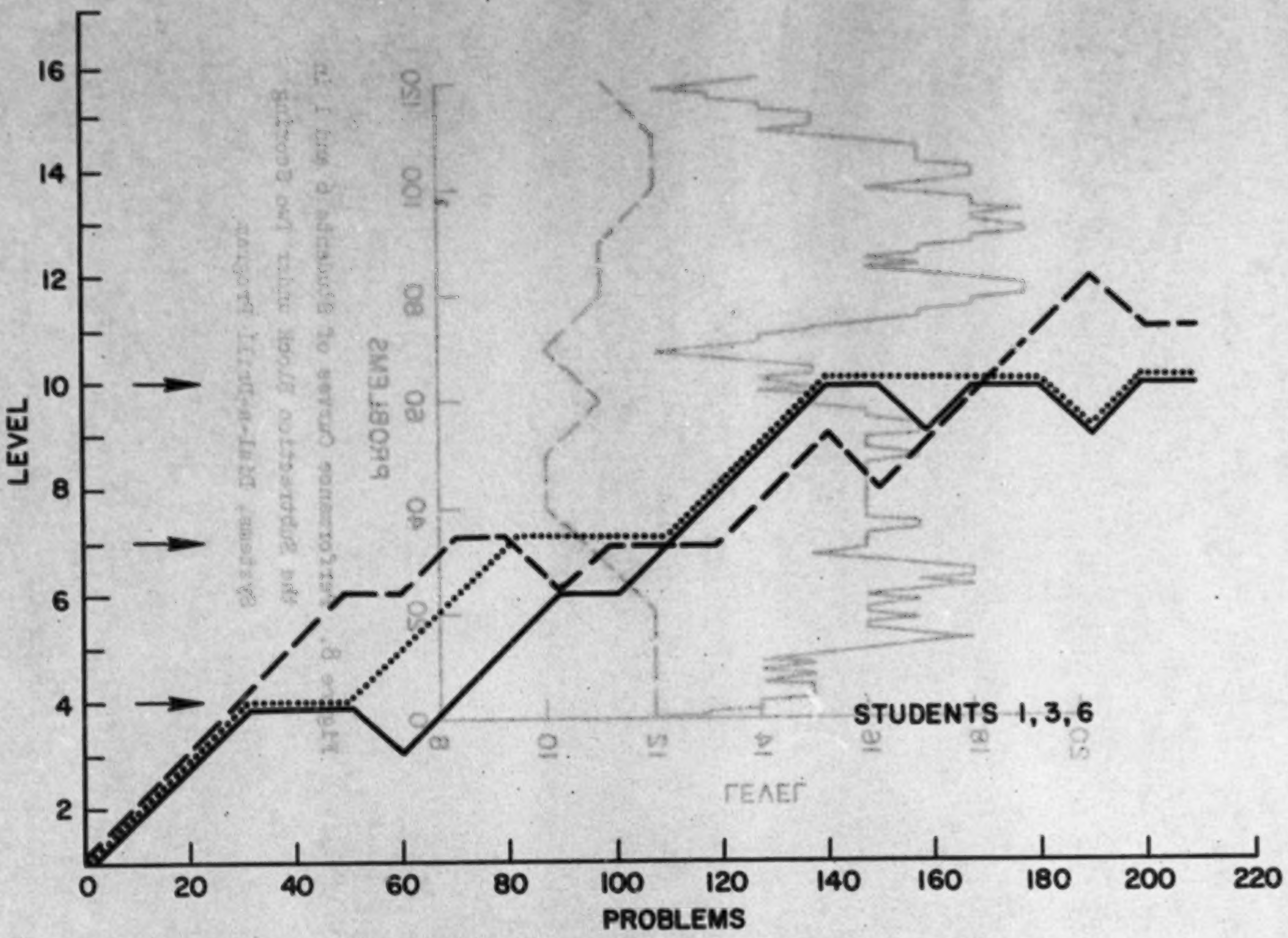

Figure 7. Performance Curves for Students 1, 3, 6 in the Subtraction Block, Dial-a-Drill Program

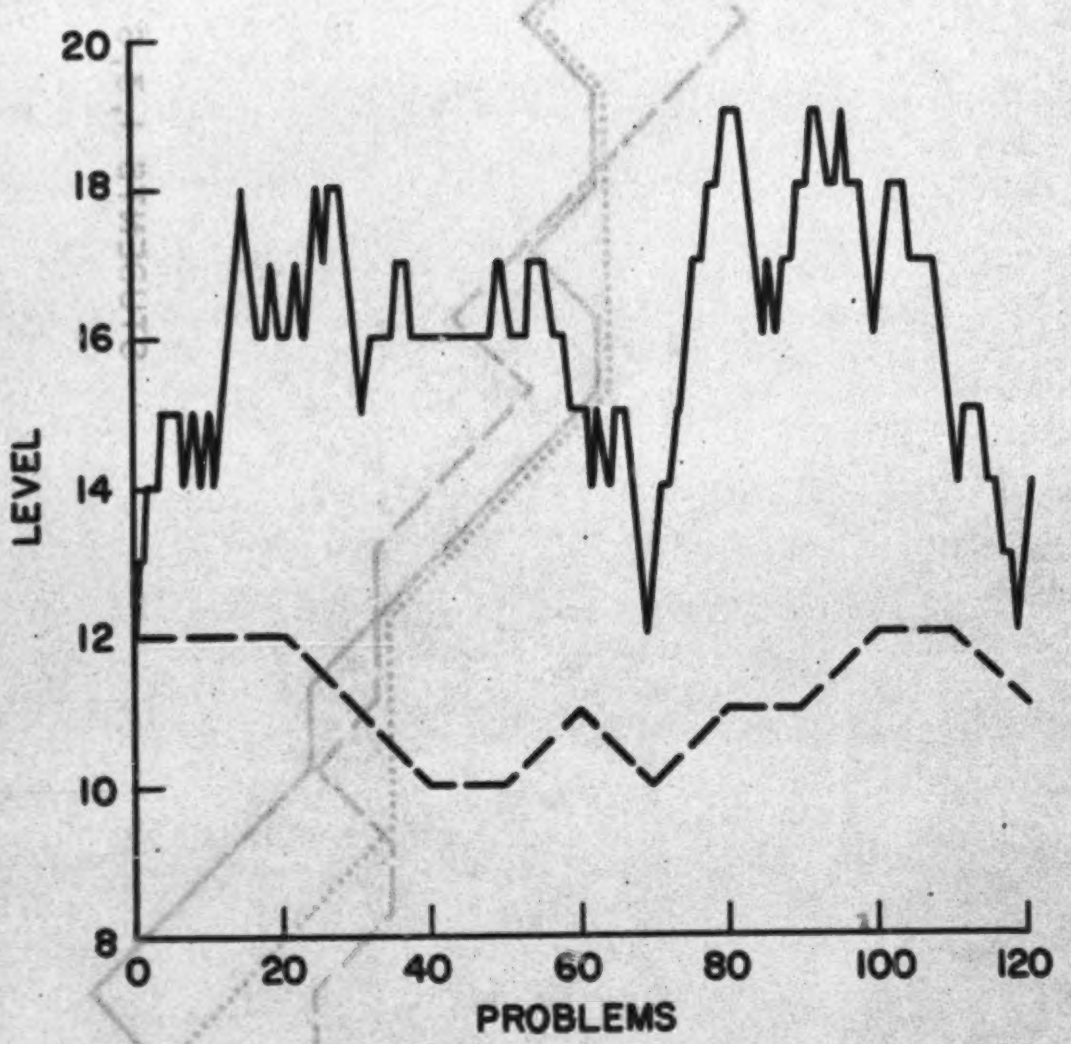

Figure 8. Performance Curves of Students 6 and 1 in the Subtraction Block under Two Scoring Systems, Dial-a-Drill Program

Figure 9 shows the progress of a student who worked from the start on the "one problem" system. A comparison with Figure 6 shows increasing failure rather than level repetition as difficulty is found.

F. Elementary Russian Program

1. Preparation of Material

Computer-based lessons. One hundred lessons have been completed and entered into the computer. Material for the remaining lessons has been selected and outlined. The data on student performance is being used in the revision of lessons already given to our students.

Language-laboratory tapes. Tapes of the type described in the previous progress report were prepared and employed at the rate of two tapes per week for the 10 weeks of the Stanford 1968 winter quarter.

Pronunciation evaluation tapes. Three additional tapes were required of our students during the period under consideration. Student performance continues to be at a high level.

Homework assignments. Homework assignments covering lessons 47 through 92 were prepared and distributed during the winter quarter.

Course summaries. A mid-term and quarter final summary, as well as individual study sheets covering the material in lessons 47 through 92, were prepared and distributed to the students.

2. Preprocessing Programs

The preprocessor has been modified to allow the lesson programmer to drill the student on the forms of a given noun, verb or adjective simply by listing (a) the basic form or forms of the stem in question; (b) the forms to be drilled; and (c) the appropriate paradigm number. The preprocessor then makes use of a set of desinence tables to generate the appropriate paradigm in a "complete-the-endings" frame.

Another improvement in the preprocessor is the introduction of a special "remedial-block" subroutine which allows the lesson programmer to convert a wide variety of frame types to the test-block structure previously available only in a single-frame format.

3. Additional Supporting Programs

The program on which lessons are run has been modified to allow the use of nested remedial blocks in future lessons. The value of these blocks will be greatly increased by permitting the students to skip some of the remedial work in a block if they respond successfully to test items within the block itself.

4. Overall Approach

No basic changes have been made in the approach discussed in our first report. The continued success of our students (see section 5) indicates that our approach is working well.

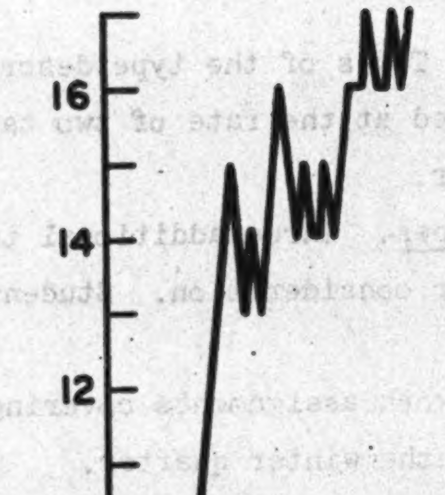

Figure 9. **Performance Curve on Student 13 in the Subtraction Block, One-problem System, Dial-a-Drill Program**

5. Results of Comparative Examinations

Approximately 66 per cent of both the mid-term and the final examinations for the winter quarter were identical both for the computer-based and for the regular Russian 1 sections. Table 23 shows results from the mid-term. Table 24 shows results from the final.

While the performance of the computer-based group continues to be superior to that of the regular group, the most striking difference is in the number of students who continued with second-quarter Russian. A much larger percentage of students remained in the computer-based group than in the regular group. In view of the fact that students who fail to complete at least one year of college Russian know too little to use the language effectively, it would appear that computer-based instruction would avoid much of the wasted time and effort which mark present-day university language courses.

6. Disk-generated Audio Stimuli

In cooperation with programmers at the Stanford Computer-based Laboratory, we have investigated various approaches to the generation of audio stimuli from the computer disk instead of from tapes. The storage of subsyllabic components was found less satisfactory than the storage of whole words, and the material needed for one of our early lessons has been listed and recorded on the disk.

7. Optional Videotape Course in the Comprehension of Spoken Russian

The preparation of videotapes of the type discussed in the last quarterly report is continuing.

G. Spelling Program

1. Individualized Spelling Lists

As part of the main experimental effort for this year, the collection of individualized spelling lists was begun and completed. These lists are 48 words long and contain words each child missed during the testing period over the 1,500-word pool contained in the program. About 350 words, with some missed by as few as 2 and some missed by as many as 30, make up the list for the 65 or so children in the main project. Each child's list then formed his words for the investigation of optimization methods in computer-based instruction spelling instruction.

The collection of the data for this experimental investigation was 90 per cent complete by the end of the quarter. Work was started on the development of analysis programs for this data.

The alternate group of students running outside the main experiment consists of very poor spellers. Because their language arts work in general is quite poor, they are not being included, as was planned, in the investigation of the enriched drill environment.

TABLE 23

Results of First-year Russian Winter Quarter Mid-term Exam
(Common Portion)
Elementary Russian Program

Number of Errors	Number of Students	
	Computer-based	Regular
4	1	
4.5	1	
5	1	
5.5		1
6	3	1
7		1
7.5	1	
8	3	
8.5	2	1
9	1	
9.5	2	2
10		1
11		2
12.5		1
13	1	
13.5	2	
14	1	
14.5		1
15	1	
15.5		1
16.5	1	1
17	1	1
18	2	
18.5	2	
20	1	
32	1	
36		1
Total number of students	28	15
Total number of errors	335.5	190
Average number of errors	12.0	12.7

TABLE 24

Results of First-year Russian Winter Quarter Final Exam
(Common Portion)
Elementary Russian Program

Number of Errors	Number of Students Computer-based	Regular
2	1	
6	1	
6.5	1	
8	1	
9.5		1
10	1	
11		1
12	2	
13		1
14.5		1
16	1	
16.5	1	
18	1	
18.5	1	
19	1	
19.5		1
21	2	
22.5	1	1
23	1	1
23.5	1	
24	1	
24.5		1
25	1	
26.5		1
27	1	
29.5	1	
30		1
30.5		1
32.5		1
33	1	
37.5	2	
38	1	
39.5	1	
41	1	2
47.5		1
Total number of students	27	15
Total number of errors:	587.5	386.5
Average number of errors	21.8	25.8

The present plan is to use the main group as soon as it has completed its work under the optimization routines.

The number of children served at the four teletypes per day continues to be slightly over 50 per day. This is about the level that was attained at the close of the last reporting period. The monthly figures are:

	Number of Days	Children per Day
Jan.	20	53
Feb.	18	52
Mar.	20	53

2. Teacher Education

As was forecast, a version of the driver designed to be used in "teacher training" activities was prepared but has not been tested nor fitted to real subjects because of the volume of work now occupying the Computer-based Laboratory. It will probably be summer before this can be done.

H. Stanford PDP-1 System

1. Hardware

A series of major hardware problems began with air-conditioning troubles during the first few weeks in January. The removal from the Stanford Computation Center of the Burroughs B-5500 computer led to a lengthy period of efforts to restabilize the machine-room air conditioning, which also serves our PDP-1. High temperatures and improper air flow patterns caused numerous failures in almost every piece of our equipment and forced several periods of complete shut-down. Most of the difficulties were resolved after three weeks, but short periods of similar trouble occurred at intervals throughout the following months.

The Mississippi PDP-8 system was down the first few days in January. Efforts to locate the trouble from Stanford were not successful, and a field engineer was called in from the DEC office in Houston. The failure was in the 637 high-speed line interface controlling the line to Stanford.

Kentucky rejoined the system during this quarter, with tests of the cross-country line and PDP-8 beginning January 17. While the Kentucky system itself has performed reasonably well, a long series of problems arose in the Kentucky-Stanford telephone line and in the computer interface to this line at Stanford. On January 26, after several days of intermittant failures, a bad circuit card was found and replaced in the 637 at Stanford. This improved the situation considerably, but remaining mysterious failures were the subject of almost daily efforts in signal tracing and circuit study. In mid-February a design flaw was found and corrected in the 637. Under certain heavy system load conditions, this bug caused the high-speed line to lose synchronization in such a way that it could be re-established only by reloading the PDP-8 program. This flaw has not yet been corrected in the 637's at Mississippi and Kentucky, since there is no indication that the critical timing condition ever arises in the remote systems.

These measures still did not completely clear up the problems, however, and efforts to locate the remaining bugs are continuing. The outstanding problem at this time is an intermittant failure which not only drops the Kentucky line, but also causes the Stanford PDP-8 to hang up, dropping all teletypes in the system.

On March 1, the power failure trap circuitry was installed in the Kentucky PDP-8, and appears to be working satisfactorily. During the latter part of March, the Kentucky PDP-8 system developed a solid failure. Diagnostic procedures indicated the trouble was in the 680 local teletype controller, and Mr. Robert Simmons was sent to Kentucky to repair it. A burned out resistor was found on one of the circuit cards.

The PDP-1 system was down for several days near the first of February for emergency maintenance on one of the 1301 disk files. The main shaft bearings had to be replaced, a major undertaking which involved complete dismantling of the mechanical assembly. Some teletype service was conducted on an emergency basis for a scheduled demonstration, and normal service was restored by February 3.

In February a punched card dialing unit and a computer-driver dial-out unit were installed for use with the dial-a-drill program. The effectiveness of each type of unit will be evaluated during extended experimental use.

During this reporting period several new instructions were added to the PDP-1. This step completes the modifications needed for the effective use of the index register.

The new Model-37 Teletype was delivered and put into service in March after a special interface to the PDP-8 was designed and constructed. This unit types 50 per cent faster than the other teletype models, and features a much larger character set, using both upper-case and lower-case letters. It will be used for high quality document printing, as well as normal listing functions within the laboratory.

2. Software and Operations

Before bringing up the Kentucky remote operation, certain modifications had to be made in both the PDP-1 and PDP-8 software. Most of these changes related simply to the increased number of teletypes in the system, but the more complicated adjustments involved the logistics of operating several remote clusters instead of only one. The PDP-8 console teletype intercom logic had to permit selective communication with several stations, and PDP-8 program loading techniques had to allow for reloading one system while maintaining normal service on all other remote clusters. The new versions of the operating systems were put into trial service beginning January 11, approximately a week before scheduled contact with the Kentucky system.

The Stanford PDP-8 program has also been keeping daily statistics on various parameters of system usage, which will influence future modifications to improve the efficiency of the system.

Especially after bringing Kentucky on-line, the system has seen extremely heavy service loads during this period. While there have been serious hardware problems, as detailed above, the software systems have become very stable. Very few system's failures can be attributed to software, and at this writing the time-sharing system has passed well over 200 hours of continuous operation since it was last reloaded.

3. Demonstrations

Remote demonstrations of the teletype programs were conducted via acoustic couplers in Palo Alto and Redwood City, California, and Houston, Texas. Evening demonstrations were also held at the Walter Hays School using their normal facilities.

I. Stanford-Brentwood System

1. Hardware

During the week of March 18, 1968, we experienced major magnetic tape problems. The daily performance tapes generated by student sessions contained several read errors, i.e., hard-tape errors. Approximately 20 single-performance records were lost. Out of an average of 5,000 records per day, this is a small number. However, the record loss will leave holes in the data. All tapes in question have been dumped, so we can see where these holes occur.

The tape problem was solved in two ways. First, several parts, including the read/write heads, were replaced on the tape unit in question. Second, a procedure for cleaning and certifying tapes was implemented.

2. Software

The group sign-on program described in the previous report was completed and is now in use. The display-graphic (DG) function was further modified to display a string of graphics, rather than just one. A display-text (DT) function was written to parallel the DG function using characters instead of graphics. To supplement the FORTRAN-function converter described in the previous report, a subroutine was written which generates response identifiers for FORTRAN-coded functions.

The weekly math report was modified to use only the first two digits of the four-digit student number to identify a student. Several minor modifications of a debugging nature were made to the daily reading report.

Several programs in the Stanford monitor were modified or rewritten. The initializer (INITZ) was completely rewritten to allow a more reasonable and flexible control card input and to interface with the CAI disk directory to check for space to put the monitor. The supervisor (LOADR) was modified to be more tightly coded. The bootstrap was modified to remove a seek command if the disk is already at home cylinder. The bootstrap punching program (BOOTP) was completely rewritten to allow punching a specified number of bootstraps for selected disk drives, rather than always punching 10 bootstraps each for all of our six drives. The pause program (PAUSE) was modified to print messages to the operator to inform him of entrances to and exits from PAUSE.

A program (LSTDK) was written to list the CAI directories of all disks which are mounted and ready at the time the program is executed. The program to sequence number a deck (SEQNR) was modified to allow arbitrary starting number and arbitrary increment.

After an initial training program, our new systems programmer, Mr. Stuart C. Miller, began the major rewrite on the tape-file maintenance program for course segments (PTTTP).

II. Activities Planned for the Next Reporting Period

A. Brentwood Mathematics Program

Manuscript production, art work, filming, recording, coding and debugging of the remaining material for this year's programmed curriculum will be completed.

The operation of the laboratory for student use will continue until the end of the school year in June.

Additional material for next year's curriculum will be written, and most of the art work and recording will also be done. Coding of the revised curriculum will commence before the end of the quarter.

Work on diagnostic tests and data analysis will also continue during the next quarter.

B. Brentwood Reading Program

During the next reporting period, the Reading Project will concentrate on data analysis and on an end-of-the-year evaluation. This evaluation will include an extensive posttesting program. A description of this testing program will be included in the next quarterly report. During the next quarter the programming staff will continue debugging Levels VI and VII to prepare them for student use.

The behavior and progress of the seven remedial fourth-grade students who began work on March 13 will be described. Also to be included will be the second set of observations of children's behavior while working at the CAI terminals.

C. Drill-and-Practice Mathematics Program

Results of the problem-solving program using the computer as a desk calculator to solve multistep problems and examination of additional variables will be reported next quarter.

The problem-solving program will be expanded considerably to include problems for third through sixth grades and beyond. The digits allowed in a number will be increased from the present six to fourteen. This will permit problems using much larger quantities than before, and should make the problems more interesting. A larger proportion of problems from science will be included in the expanded program.

D. Logic and Algebra Program

1. The First-year Program

As students continue to complete the first-year lessons, they will be put into the second-year program.

Work with the audio link will be continued. The tapes will be studied to see if student questions can be standardized into a simple code which students can use at the keyboard, since computer recognition of student speech is not now possible. At the same time, answers will be examined to see if they can be condensed into a manageable list of recorded messages. The next step would be to write a program for selecting appropriate audio messages to respond to student question codes.

2. The Second-year Program

The remaining lessons of the second-year program will continue to be written and coded.

3. The Third-year Program

The next quarter will be devoted primarily to writing lessons which are concerned with simultaneous linear equations. The corresponding part of the geometry booklet will also be prepared.

E. Dial-a-Drill Program

We plan to reassess the difficulty of the equivalence classes within the strands according to observations of the students that are presently running.

Since we plan to continue the procedure of evaluation after each problem, it will be necessary to tighten the definitions of each equivalence class and, as a result, to increase the number of classes per strand.

F. Elementary Russian Program

In the next quarter we plan to complete our computer-based course. Two language-laboratory tapes will be made per week and a homework assignment and a study sheet will be issued for each computer-based session. Comparative data on the computer-based and regular groups should be obtained from the Stanford spring quarter mid-term and final exams, and at least three more pronunciation-evaluation tapes will be required from each of the computer-based students.

The drill-generating routine will be coordinated in the preprocessor with a set of coded form-generation rules which will include data on remedial-block responses. This should lay the basis for the generation of individualized form drills on the basis of a day-by-day analysis of student performance.

A construction-drill generator and a routine to generate analytic nested remedial blocks for certain types of construction will begin.

The listing and recording of disk-generated stimuli for the early parts of our course will continue.

Preparation of videotape material will continue.

We will continue to use the results of the data analysis in revising the remaining portion of our course.

G. Spelling Program

The major activity for the next quarter will be the analysis of the data generated by the experimental study of optimization routines.

The experimental investigation of the effect of an enriched drill environment will be the main activity for the spelling program itself. The rationale behind this study is contained in Lorton (1968).

H. Stanford PDP-1 System

During the next several months we anticipate a growing emphasis on hardware work. Most of the staff will be involved with at least one of several major projects. Final design, construction, and interfacing should complete the core-memory multiplex system. A special data channel must be designed and built for the new IBM 2314 disk file due for delivery in July. Equipment selection and interface design is also anticipated for several other major items.

I. Stanford-Brentwood System

The modifications to PTTTP will be completed. The major undertaking will be to document the systems software and operating procedures in all areas of Systems and Operations Group responsibility.

III. Personnel

Brentwood mathematics program. Miss Briana Burns, technical editor, left the staff in January as did Mrs. Sharon Forstenzer. Miss Gail Richens was hired as a computer operator and Miss Carol Christensen as a proctor-writer.

Brentwood reading program. Mrs. Meredith Smith, Mrs. Dana Jones, and Miss Christine Herlick resigned from their positions as curriculum writers. Miss Kathy Thomas became a full-time coder and Mrs. Helen Bernard resigned from the coding staff.

Stanford-Brentwood system. Mr. Stuart C. Miller joined the staff as full-time systems programmer.

Logic and algebra program. For the second-year program, Klaus Galda, Bob Titiev and Marilyn Cox will alternately supervise the teletype room at Walter Hays. Joseph Offir, Research Assistant, was assigned to assist with data analysis. Klaus Galda worked on the third-year program this quarter.

Elementary Russian program. Cordy Bodkin was replaced by Irene Brunot.

IV. Dissemination

A. *Publications*

Atkinson, R. C. Computer-based instruction in initial reading. *Proceedings of the* 1967 *Invitational Conference on Testing Problems*. Princeton, N. J.: Educational Testing Service, 1968. Pp. 55-56.

Atkinson, R. C. The role of the computer in teaching initial reading. *Childhood Education*, 1968, *44*, 464-470.

Lorton, P., Jr. Increasing teacher-like behavior within computer-based drill-and-practice programs. *Stanford Review of Education*, 1968, *3*, 34-42.

Suppes, P., Hyman, L., & Jerman, M. Linear structural models for response and latency performance in arithmetic on computer-controlled terminals. In J. P. Hill (Ed.), *Minnesota Symposia on Child Psychology*. Minneapolis: Univ. Minn. Press, 1967. Pp. 160-200.

Suppes, P. Some theoretical models for mathematics learning. *J. of Res. and Development in Educ.*, 1967, *1*, 5-22.

B. *Lectures*

Anselm, K. Look, look, see CAI. Lecture presented at Brentwood to ARE, Classroom Teachers Committee, Richmond, California, February 1, 1968.

Anselm, K. Computer control...does not compute. Lecture presented at Conference on New Educational Technologies, Higher Education Seminar, United States Student Press Association, San Mateo, February 23, 1968.

Anselm, K. What to do until the computers arrive. Lecture presented at New Educational Technologies, Higher Education Seminar, United States Student Press Association, San Mateo, February 24, 1968.

Anselm, K. Read the signs: the school of the future is here today. Telelecture via telephone, Educational Media Specialist Institute, University of Colorado, Boulder, March 9, 1968.

Atkinson, R. C. Models for short-term memory. Seminar presented at the Psychology Department, University of Toronto, January 23, 1968.

Atkinson, R. C. Computer application in teaching. Lecture presented at the Ontario Institute for Studies in Education, Graduate Department, School of Education, University of Toronto, January 23, 1968.

Atkinson, R. C. Computerized instruction and the learning processes. Invited lecture presented at the Educational Research and Development Council, University of Minnesota, Minneapolis, January 25, 1968.

Atkinson, R. C. Some speculations on storage and retrieval processes in long-term memory. Invited lecture presented at the NASA Conference, Ames Research Center, February 2, 1968.

Atkinson, R. C. Some two-process models for memory and learning. Two lectures presented at the Institute of Human Learning's Research Seminary, University of California, Berkeley, February 7, 14, 1968.

Atkinson, R. C. Computerized instruction and the educational process. Lecture presented at the School of Education, University of California, Santa Barbara, February 20, 1968.

Atkinson, R. C. Some two-process models for memory. Colloquium presented at Department of Psychology, University of California, Santa Barbara, February 20, 1968.

Atkinson, R. C. Computer-based instruction. Invited lecture presented at American Society for Curriculum Development, Atlantic City, March 11, 1968.

Berkowitz, L. D. Computer-based instruction in arithmetic (the drill-and-practice program). Seminar in CAI, School of Education, Stanford University, January 24, 1968.

Binford, F. H. Computer-assisted instruction in logic. Lecture presented at Northern California Teachers of Mathematics, Sacramento Conference, March 30, 1968.

Friend, J. E. Mathematics at Brentwood. Lecture presented at seminar on computer-assisted instruction, Stanford University, Stanford, California, January 31, 1968.

Friend, J. E. The first year-and-a-half at the Stanford-Brentwood Computer-assisted Instruction Laboratory. Lecture presented at seminar on computer-assisted instruction, Orange County Elementary Administrators Association, Anaheim, California, February 21, 1968.

Friend, J. E. Geometry in the primary grades. Lecture presented at Regional Mathematics Conference of the California Mathematics Council, Northern Section, and Sonoma, Lake, Mendocino County School Offices, Ukiah, California, February 24, 1968.

Friend, J. E. Mathematics at Brentwood. Lecture presented at seminar on computer-assisted instruction, Stanford University, Stanford, California, March 5, 1968.

Friend, J. E. Computer-assisted instruction. Lecture presented at Laura M. Hansen Home and School Club, Saratoga, California, March 18, 1968.

Jerman, M. Computer frontiers in teaching. Two lectures presented at the Individualized Instruction Conference, Cabrillo College, Aptos, California, March 23, 1968.

Jerman, M. Workshop in computer-assisted instruction conducted at Morehead State University, Morehead, Kentucky, February 1-3, 1968.

Suppes, P. Survey of computer-assisted instruction. Institute for Computer-assisted Instruction, Rickey's Hyatt House, Palo Alto, January 16, 1968.

Suppes, P. Computer-assisted instruction at Stanford. Lecture presented to Faculty Women Newcomers, Stanford University, January 18, 1968.

Suppes, P. The use of computers in education. Lecture presented at Century 21 Lecture Series, Stanford University, February 6, 1968.

Suppes, P. A look at the data. Lecture presented at AERA Symposium on CAI: Bane or Boone?, Chicago, February 8, 1968.

Suppes, P. Problems of evaluation in computer-assisted instruction. Lecture presented at Education Development Center, Cambridge, Massachusetts, March 5, 1968.

Suppes, P. Problems and prospects of computer-assisted instruction. Lecture presented at Colloquium, Education Research Center, Massachusetts Institute of Technology, Cambridge, March 6, 1968.

Suppes, P. Computer-assisted instruction. Lecture presented at Workshop on Computers, San Mateo County Board of Education, March 13, 1968.

Suppes, P. Systems analysis of computer-assisted instruction. Principal speaker at Session on Education at the Forum on Systems Analysis and Social Change. Annual Meeting of American Institute of Aeronautics and Astronautics, Washington, D. C., March 18, 1968.

Suppes, P. Stimulus-response theory of language learning and the theory of automata. Invited lecture presented at Western Psychological Association, San Diego, March 29, 1968.

Wilson, H. The Stanford CAI Project. Lecture presented at Institute for Computer-assisted Instruction, Palo Alto, California, January 16, 1968.

Wilson, H. Computer-assisted instruction in the elementary schools of New York City. Participant, panel discussion, national convention of the American Association for School Administration, Atlantic City, New Jersey, February 19, 1968.

Wilson, H. Dialogue No. 45: Technological Innovations. Participant, panel discussion, Association for Supervision and Curriculum Development, Atlantic City, New Jersey, March 11, 1968.

C. Visitors

Stanford-Brentwood Laboratory. Visitors to the Laboratory numbered 760 individuals during this reporting period. Included in that number was one group of 80 visitors representing 44 institutions of higher learning.

The large number of groups and range of interests have on occasion made it necessary for over a dozen project staff members to assist with the visitors. Special interest areas included computer hardware; computer software, mathematics-curriculum development; reading-curriculum development; inservice education; data analysis and reduction; project laboratory facilities; teacher education for this environment, etc.

Regularly prescheduled visiting times have been in effect throughout the reporting period, while special arrangements have been made to accommodate large groups of teachers, students, or foreign visitors who cannot fit into the regular schedule. Although most groups to the Laboratory number fewer than 10 because of limited space, there have been groups as large as 18.

Each Laboratory visitor spends about one hour viewing children at the terminal equipment, interacting with a staff member concerning the project, and actually working through instructional material. During the morning hours when reading instruction is provided for the children, the visitor terminal utilizes a special Reading Demonstration course which describes the reading program in detail. Special sections of the mathematics materials are available to visitors during the afternoon hours when mathematics instruction is offered.

Drill-and-Practice Program. Approximately 260 visitors visited the drill-and-practice program at local schools by special appointment. They were given an opportunity to observe the students at the terminals, to talk to a staff member about the program and, in many cases, to work at a terminal on a demonstration lesson.

Groups of visitors numbered from two to four persons, although larger groups were scheduled on occasion. Educators, students and business executives from this country and abroad comprise individuals interested in the project.

Aspects of the program discussed on the tours were curriculum and its development; the computer system, including both hardware and software; the reaction and involvement of the children, teachers, and administration. Visitors were also given descriptive literature concerning the project.

Elementary Russian Program. Forty-five to 50 persons visited the computer-based first-year Russian classroom at Stanford. Interest centered around the procedure for teaching the course and the cost of initiating and maintaining this program. All the visitors observed students working at the terminals and most of the visitors took the first lesson of the course. Time allotted for an average visit is 45 minutes.